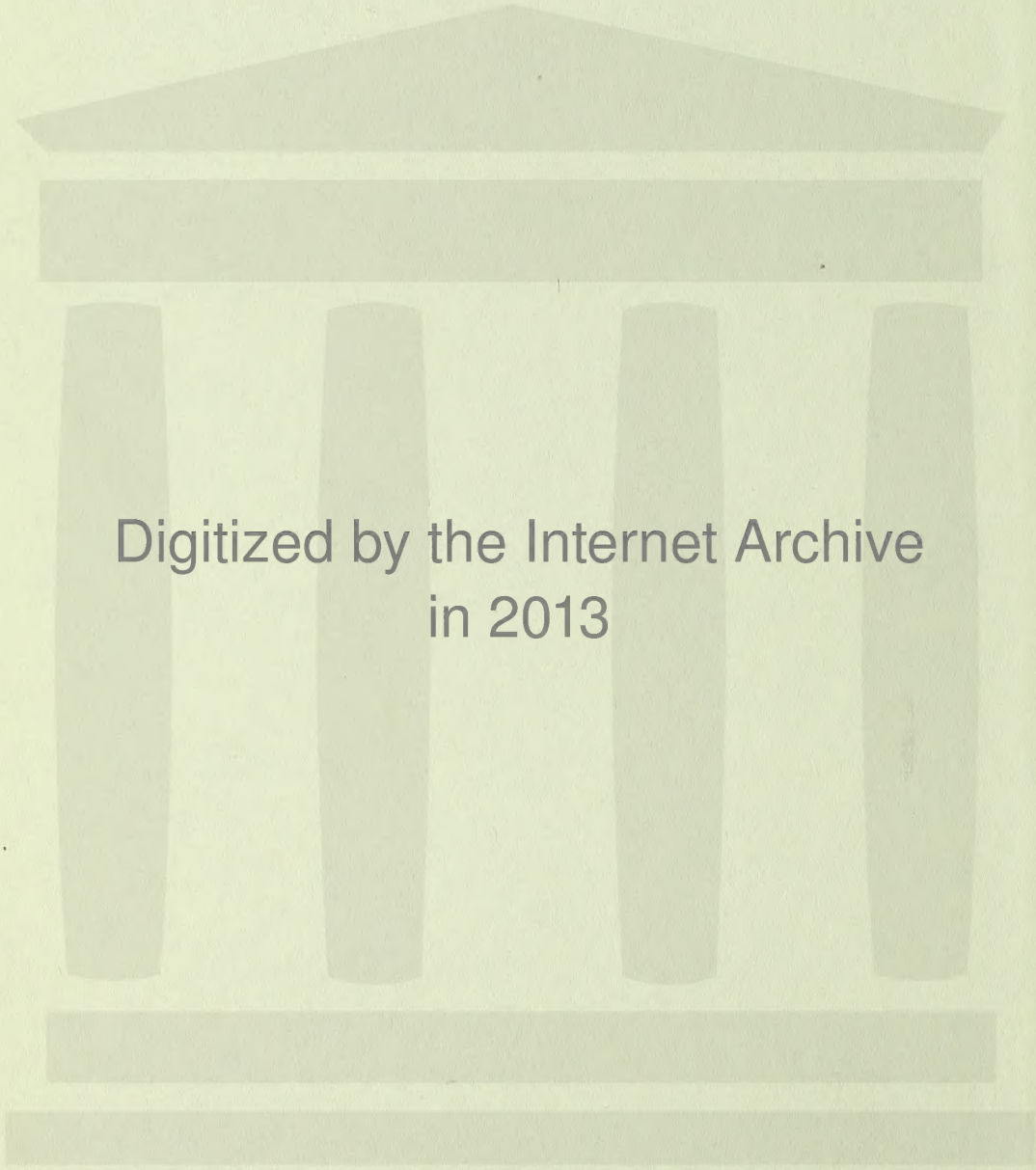

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The Use of Chemicals to Control Inferior Trees in the Management of Loblolly Pine

by

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FOREST SERVICE

U. S. DEPARTMENT OF AGRICULTURE

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FOREWORD

During the past 5 years the Southeastern Forest Experiment Station has been investigating the behavior and control of inferior trees in the management of loblolly pine. The ecological problems and possible methods of solution were discussed in Technical Note 72, released by this Station in April 1949, "The behavior and control of understory hardwoods in loblolly pine stands," by L. E. Chaiken. It was pointed out in that publication that weed trees could be controlled by prescribed fire, by mechanical methods, by chemicals, and by hand tools. But it was also clearly stated that not a single one of these could be considered a cure-all by the forester harassed with "brush."

The investigations reported in Technical Note 72 have been continued, with particular emphasis upon the use of chemicals. Now, on the basis of records of more than 10,000 treated trees, we can evaluate the usefulness of chemical control. In doing so, we are fully aware that the final word has not been written, but what we have learned during the past 5 years, and what we think it means, is reported here.

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THE USE OF CHEMICALS TO CONTROL INFERIOR TREES IN THE MANAGEMENT OF LOBLOLLY PINE

by

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A sales executive of a large chemical company once predicted that the use of chemical weed killers would eventually be greater for the control of brush and woody plants than for the control of weeds in agricultural crops. That was four or five years ago when only scattered tests were being made of the newer herbicides to determine the possibilities of controlling woody species. The sales executive will be pleased if his prediction comes true, but the forester cannot help being impressed by the tremendous increase in the use of these chemicals. For example, it is estimated by Stahler (7) that over a million acres of mesquite will be chemically controlled during 1951 on the Texas ranges. And over the country hundreds of thousands of miles of rights-of-way have been treated for the control of brush and tree sprouts.

What use can foresters make of the chemicals? Or, more specifically, as far as this publication is concerned, how can these chemicals aid in the management of loblolly pine in the Carolinas? Let's look at the problems. In common with all other timber-producing forest types throughout the country, our sole silvicultural objective is to sustain well-stocked stands of valuable tree species adapted to the site. Like many other forest types, much of our forest land is occupied by inferior trees. Obviously, any space on the forest acre occupied by trees of inferior species or quality is just so much space unavailable to trees of higher value.

In the loblolly pine region of the Carolinas, the problem of aggressive hardwood weed species is particularly acute. During the past two decades there has been a steady building up of dense undergrowths, mainly of sweetgum, with local associations of blackgum, oaks, southern waxmyrtle, gallberry, and hickories. Their growth rate is accelerated

when they are released by the removal of part or all of the pine overstory, and competition with the pine reproduction becomes quite severe. On many sites there is a very definite type conversion--from pure pine to pine-hardwoods mixtures, and eventually, perhaps, to almost pure hardwoods.

There are two ways that a forester can meet this problem. First, he can provide more pine seed and better conditions for germination. And second, he can physically subordinate or remove the inferior trees. In either case he attempts to achieve the purpose of increasing the pine component. Practically, however, he often has to do both.

Methods of increasing the loblolly pine seed supply and improving the seedbed are currently being studied, and progress reports have been issued by Pomeroy (6) and Trousdell (8). Decreasing the hardwood component by prescribed fire, by mechanical methods, by chemicals, and by hand tools has been reported by Chaiken (2) and others.

Tree poisoning is not a new notion.--At least 25 years ago, studies were made of the use of arsenicals, principally sodium arsenite. Since then many chemicals have been tried, with varying success. Among these were: sodium and calcium chlorate; potassium chromate and bichromate; copper and iron sulphate; copper, sodium, barium, and zinc chloride; ammonium thiocyanate; formaldehyde; carbolic acid; sodium fluoride; ethyelene oxide; cresylic acid; kerosene; creosote; and many others (1). None, however, was entirely satisfactory, either because of ineffectiveness, toxicity to the user, or because of high cost. Interest lagged in the use of tree poisons until the end of World War II, when a number of newly developed chemicals came into use. Undoubtedly the reawakening of interest has been stimulated by the remarkable success of these chemicals as selective herbicides. In any event, foresters began to ask, "What are these chemicals and what can they do for us?"

THE CHEMICALS

Ammonium sulfamate (much better known by its trade name "Ammate") was for many years considered an interesting but useless product until its herbicidal properties were discovered about 10 years ago. Ammate is generally used in its dry crystalline form or as a water solution, and occasionally emulsified with oil. It is non-toxic to humans, wildlife or livestock but may cause minor skin irritation under prolonged contact. Its residual effect as a soil sterilant is negligible for forest uses. However, Ammate is quite corrosive to ordinary metal containers, so that stainless steel or protectively coated equipment should be used.

2,4-Dichlorophenoxyacetic acid and 2,4,5-Trichlorophenoxyacetic acid (simply abbreviated as 2,4-D and 2,4,5-T, respectively) are related plant hormone compounds now widely known, especially the former, for their ability to kill weeds. The acids themselves are seldom, if ever, used as weed killers--rather they are formulated as metallic salts, amine salts, and esters. Although there are many of these to choose from, the forester need not be troubled in making a selection. The low volatile esters of these chemicals, such as the butoxy ethanol or the propylene glycol butyl ether ester, have thus far proved to be more effective in the control of inferior tree species in the Carolinas than any of the other formulations we have tested. Therefore, unless otherwise specified, future reference to 2,4-D or 2,4.5-T in this publication will mean these low-volatile esters.

Neither 2,4-D or 2,4,5-T is harmful to the user or to wildlife and livestock. They are also non-corrosive, which gives them some advantage over Ammate. And like Ammate they have little residual effect as soil sterilants. Preparations of 2,4-D and 2,4,5-T are marketed as liquid concentrates that are diluted before use. The diluents, or carriers, may be either water or such petroleum oils as kerosene, fuel oil, or diesel oil, depending upon the use that is made.

Other chemicals are used as silvicides. Sodium arsenite, for example, is one of our most effective tree poisons, but it is hazardous to use. It has given excellent control of many tree species, such as

bitter pecan in the Mississippi Delta (4). Both in Canada and this country, sodium arsenite is coming into greater use to serve the double purpose of killing trees and making their bark easy to peel. Yet the forester in the Southeast, where stock grazing is frequently uncontrolled, is reluctant to take the risk of using a chemical as highly toxic as sodium arsenite.

Sodium chlorate, polybor chlorate, the dinitros and the trichloroacetates, as well as dozens of other chemicals, even borax and common salt, will injure woody plants. None of these is as widely useful to the forester as Ammate, 2,4-D, and 2,4,5-T.

CONCENTRATION AND DOSAGE

Concentrations of these chemicals are expressed in different ways. Using the water emulsion of one of the low-volatile esters of 2,4,5-T as an example, concentration may be given as: (1) the ratio of the weight of the 2,4,5-T acid equivalent of the 2,4,5-T ester to the combined weight of the water carrier plus acid, expressed as a proportion; e.g., 10,000 parts per million, or (2) the same ratio expressed as a percentage; e.g., 1 percent acid by weight, or (3) the ratio of the volume of the manufactured product or concentrate to the volume of the water carrier, expressed as a percentage; e.g., 2 percent by volume. If the product as marketed contains the equivalent of 4 pounds of 2,4,5-T acid per gallon of 2,4,5-T ester concentrate (as is now common marketing practice), then the three expressions of concentration cited above are equivalent; that is, 10,000 parts per million = 1 percent acid equivalent by weight = 2 percent of the product by volume. The latter expression of concentration is quite simple to understand. A solution of 2 percent 2,4,5-T (by volume) may be prepared by adding 1 gallon of the concentrate to 49 gallons of water (50 gallons of water would be close enough).

Solutions or emulsions of 2,4-D or 2,4,5-T of any desired concentration are easily prepared by following the proportions given in

table 1, if the commercial product or concentrate contains the equivalent of 4 pounds of acid per gallon.

Table 1.--Approximate proportions of commercial product (containing 4 pounds of 2,4-D or 2,4,5-T acid per gallon) required to prepare solutions or emulsions of desired concentrations

Concentration by weight of acid		Concentration by volume of concentrate	Volume of product to make 1 gallon of solution		Volume of carrier to add to 1 gallon of product
(Percent)		(Percent)	(Milliliters)	(Ounces)	(Gallons)
		WATER CARRIER			
1/4	=	1/2	20	= 2/3	200
1/2	=	1	40	= 1-2/3	100
1	=	2	80	= 2-1/2	50
		OIL CARRIER			
1	=	1-2/3	65	= 2	60
2	=	3	125	= 4	30
3	=	5	200	= 6-1/2	20
5	=	8	325	= 10	11
6	=	10	400	= 13	9

Concentrations of Ammate solutions are usually expressed as "pounds of Ammate per gallon of carrier," rather than in terms of the active ingredient, ammonium sulfamate (of which Ammate contains 80 percent).

For agricultural crops a favored expression of concentration, particularly for 2,4-D is "pounds of acid per unit area." More precisely, it is an expression of dosage rather than concentration, and as such gives an accurate statement of the amount of active ingredient applied. The usefulness of this expression becomes apparent when we consider that a given acre can be treated with either 60 gallons of 1-percent (by weight) solution of 2,4-D or with 12 gallons of 5-percent solution. In both cases, 4 pounds of 2,4-D acid have been applied per acre. Since it is the active ingredient that does the weed killing, both dosage and concentration must be known.

For forest crops, however, expressions of dosages are quite difficult to make. In the first place, "pounds of acid per acre" is of little value because of the tremendous variability in the amount of brush or weed trees from acre to acre or from one forest property to another. In the second place, there is the practical difficulty of measuring or even estimating how much chemical solution is being applied if individual trees are being treated. And finally, we know that the amount of active ingredient is not always an index of tree-killing capacity. For example, very light dosages or low volumes of high concentrations will not kill basal-sprayed trees, although a lesser amount of active ingredient applied as a higher dosage will do so. As a consequence, we have resorted to recommending spray dosages in such inexact terms as "to the point of runoff," or "as much as the tree will take."

METHODS OF APPLICATION

These chemicals have been applied to the weed trees or brush in just about every imaginable way: to the foliage, to the bark, on wounds, on stumps, in notches, in frills, and in slits. Any method will work that introduces enough of the toxic material into the conducting tissues of the tree. Some methods, though, use the chemical more efficiently than others, so that a minimum amount need be applied. And some methods are easier and cheaper to perform. Some species react differently to different methods; as an illustration, sweetgum is readily killed by foliage sprays of 2,4,5-T but is slow to respond to basal sprays. Just to be contrary, some of the oaks are easily killed by basal sprays but sprout vigorously after foliage sprays. The choice of method of application further depends upon size of weed trees, number of stems or amount of brush, quantity and size of desirable trees, availability of suitable labor and equipment, and, finally, the aim of management.

For convenience, the methods of application have been grouped as: (1) foliage sprays, (2) cut surface methods, and (3) basal sprays.

Foliage sprays

It is natural that the most extensive use of these chemicals for the control of woody plants has been as foliage sprays, since treatment is readily applied to masses of brush. Such area-wise control is usually more economical than stem-by-stem treatment where the stems are small and very numerous. Early in our investigations we found, as others have, that just about all the foliage must be treated in order to kill the root system of any given plant. Because it is inefficient to spray all the foliage of large trees, and also probably ineffective, it has become common practice to first reduce large stems by cutting or fire and then spray the resultant sprouts.

Complete eradication of all brush is seldom accomplished by a single spraying, although several repeated sprayings will eliminate all susceptible species. This is illustrated in figure 1. Here are adjacent plots in a 45-year-old loblolly pine stand. Figure 1A is a view of the untreated plot, showing the typically dense brush-like understory of undesirable hardwoods. A prescribed winter fire followed by a single spraying of the foliage of 1-year-old sprouts killed at least 80 percent of the hardwood root stocks, as illustrated in figure 1B. By spot spraying the survivors during the following two successive years, we eliminated practically all the brush, as in figure 1C.

For forest management purposes, however, complete eradication is not needed--nor, indeed, is it even desired. So, if an adequate pine seed source is available to restock the area promptly, or if planting soon follows the clearance of the brush, the control accomplished by a single foliage spraying should be sufficient. Existing or advance pine reproduction cannot be relied on, because the preparatory fire or mechanical disking will, of course, eliminate pine as well as reduce brush. Even if fire or disking is not used, the present chemicals in our foliage sprays are also toxic to pine reproduction, as well as to brush. This method, then, is useful only when we desire to regenerate even-aged stands.

Figure 1A.--Typical of many in the Carolina flatwoods, this 45-year-old loblolly pine stand has a dense understory of gums, oaks, and other inferior species. Occasional large hardwoods are in the overstory.

Figure 1B.--A single foliage spray will eliminate many of the brush-like hardwoods. This plot is adjacent to that shown in figure 1A.

Figure 1C.--Although such control is not necessary, several repeated foliage sprays will eradicate practically all woody vegetation. Grasses quickly replace the hardwood brush.

2,4,5-T for foliage sprays.--All things considered, we believe that the most efficient foliage spray for the species associated with loblolly pine in the Carolina flatwoods is a water emulsion of 1/4 of 1 percent low-volatile esters of 2,4,5-T (acid equivalent by weight). The emulsion may be prepared, as directed in table 1, by adding one gallon of 4-pound commercial product to 200 gallons of water. One gallon of the emulsion or spraying solution as mixed costs about 6 cents. There are other foliage sprays, and some cheaper too, so our experience with them will be reviewed briefly.

When we first began to investigate foliage sprays some years ago, we examined the cheaper chemicals. Early tests with the ammonium and sodium salts of 2,4-D looked quite promising, but we later found that our good results were directly tied in with season of application. For example, a satisfactory kill of sweetgum and associated species was obtained only when we treated during the midsummer, about the time of the formation of the terminal buds. The amine salts of 2,4-D also gave unreliable results. The esters of 2,4-D were much better than the salts but yet not as effective as 2,4,5-T. Nor were combinations of 2,4-D and 2,4,5-T as effective as equivalent or even lower concentrations of 2,4,5-T alone. Solutions of Ammate at 3/4 to 1 pound per gallon of water have reportedly given results as good as 2,4,5-T and sometimes much better. although at a cost two to three times as high. The greater cost and the corrosive properties of Ammate make it less useful for forest management purposes than 2,4,5-T as foliage sprays. We might add that tests of these chemicals showed that an increase in concentration over the minimum effective concentration did not bring about a corresponding increase in effectiveness of kill.

Spray any time after full leafing.--Until later investigations proved otherwise, most research workers believed that these chemicals were more effective when applied to young succulent foliage. While that may have been so for young seedlings, these chemicals, applied to woody plants with well-established root systems, quickly destroy succulent foliage but fail to kill the roots. Perhaps this is because of the limited leaf

area sprayed or the initial vigor of spring growth, but at any rate we have found that 2,4,5-T gives better root kill if applied after full development of the foliage.

Species susceptibility varies.--The foliage of practically all tree and woody shrub species encountered in the Carolina flatwoods is killed by sprays of Ammate or 2,4,5-T, some species more readily than others. However, defoliation does not mean that the roots are destroyed--some species and some individuals will resprout. It is difficult to list species susceptibility, for there is wide variation within as well as between species. Sweetgum, for example, is usually quite susceptible to foliage sprays of 2,4,5-T but there are areas where resprouting has been greater than anticipated. We do not know why. In general, we can expect little resprouting after foliage sprays of 2,4,5-T on sweetgum, blackgum, southern waxmyrtle, and gallberry. Many oaks will resprout, and these are better controlled with Ammate. A few species, such as catalpa and sweet bay, fortunately less common in loblolly pine, seem to resprout just as vigorously after spraying as after mere cutting of the stems.

Woods spraying requires heavy equipment.--In contrast to the ease of spraying rights-of-way, woods operations are rather cumbersome. From 50 to 150 gallons of solution are required to treat an acre of 1-year-old sprouts, so that a tremendous amount of water will be consumed on large areas. Large capacity tanks are needed to haul this water into the woods and heavy motive equipment is needed to haul the tanks. Even in our level flatwoods areas it is frequently difficult to maneuver heavy equipment.

Foliage spraying by aircraft has been used in the extensive brush and range lands of the West and Southwest, but is poorly adapted to the Southeast. Our forest lands are usually in small blocks, intermingled with farm lands, and the chemicals used in brush control are highly toxic to most agricultural crops. Furthermore, the best time to control brush is before it takes over the forest; that is, when it is still a relatively innocuous understory in pine stands--and not easily sprayed by aircraft. All methods of spraying foliage, and particularly when fog machines and mist sprayers are used, require caution to prevent drift into areas of susceptible farm crops.

Foliage sprays are expensive.--A 6-acre block of quite dense 1-year-old sprouts was sprayed at a cost of $11.62 per acre, broken down as follows:

		Cost per acre
Chemical:	125 gallons of 1/4 of 1% 2,4,5-T at $0.06 per gallon	$ 7.50
Equipment charges:	0.5 hours of pump, tank and tractor operation	2.50
Labor:	Tractor operator - 0.5 man-hours at $1.00	.50
	Spraymen - 1.5 man-hours at $0.75	1.12
	Total cost per acre	$ 11.62

(The above are on-the-job costs only, and do not include overhead, transportation, etc.)

This is a costly operation, although other, less dense areas might be treated for about $8.00 per acre. Yet, if the failure to control the brush results in only a partial pine stand, perhaps the investment is justified. Oddly enough, owners occasionally forget that no amount of brush control will produce seedlings unless pine seed is available.

There are other ways to control brush.--Even though single prescribed fires reduce only the size of the stems of inferior species, and seldom the number, they usually exert sufficient control and encourage the regeneration of loblolly pine. Burning is cheaper than spraying foliage. Both size and number of competing stems can be reduced by some mechanical means, such as disking, at a greater cost than prescribed fire but still cheaper than foliage sprays. Almost complete eradication can be obtained, at a rather considerable cost, by either foliage sprays or some such mechanical clearing, as bulldozing. The forester can get just about as much control as he is willing to pay for.

Cut surface methods

Another way to apply these chemicals is to introduce them into the trees through some sort of cut in the stem, such as notches, frills, and incisions, or on the stumps or stubs of felled trees. Since individual stems are treated, it is easy to see that this procedure is usually not applicable to masses of brush, where there may be thousands of stems per acre. Ordinarily, the cut surface methods are used to liberate existing and desirable but overtopped reproduction. It is often difficult to choose which trees to release and which to deaden. This choice depends upon present and expected local markets, and must rest with the individual forest manager.

Should we girdle or poison?--Over the years many trees have been girdled to liberate desirable reproduction. There have been failures and successes--some trees fail to die after girdling, others persist for a long time before dying, and many trees resprout. Nevertheless, with the exception of certain hard-to-kill species, as beech, sweetgum, and blackgum, girdling has generally been effective. So, if tree poisons are to be used, they must offer something more than mere girdling. Without question, the tree poisons are more effective than girdling. They kill trees more surely and more quickly, with little or no resprouting. But there is some question about comparative costs; some poisoning methods appear to be as cheap, or even cheaper than girdling--others definitely cost more.

Ammate crystals in notches.--During recent years one of the most popular methods of poisoning individual trees has been the use of dry Ammate crystals in notches or cups chopped in the base of the tree, as in figure 2. Peevy (5) recommends that a level tablespoonful (about 1/2 ounce) of Ammate be placed in each notch, and the notches be spaced 6 inches apart from edge to edge. Reports of the failure of this method to kill trees of certain species or at some season of the year appear to be due to inadequate dosage. We have found, in the Carolinas, that an increased dosage of a heaping tablespoonful of Ammate (about 1 to 1-1/2 ounches per notch) will kill the species associated with loblolly pine, and at any season of the year.

Figure 2.--Most tree species can be quickly killed by using Ammate crystals in notches or "cups."

The cost of this method is high, from one-and-a-half to two times the cost of double-hack girdling, but the results are excellent. It gives the quickest kill of more species than any other method and chemical we have tested (with the exception of sodium arsenite, which is not acceptable for general use).

Ammate solution in frills.--As recommended by Peevy, a 19.3-percent solution of Ammate (at 2 pounds per gallon of water) is poured into single-hack girdles or overlapping ax cuts encircling the tree.

The cost is about half that of using crystals in notches, and roughly about the same as the cost of double-hack girdles. However, it is less effective than the notch method, but decidedly more effective than girdling. Some basal sprouts are to be expected and an occasional tree will resprout in the crown, apparently recovering entirely from the effects of the chemical. The southern oaks, with the exception of live oak (Q. virginiana), are readily killed by this method. Beech and hickory are difficult to kill, and sweetgum and blackgum are moderately so.

2,4,5-T in frills.--A variant of the above frill technique, using low concentrations of 2,4,5-T rather than Ammate, offers very good control at a moderate cost. An emulsion of 1 percent 2,4,5-T (by weight) costs a little less than a 2-pound solution of Ammate, so treatment should cost about the same as double-hack girdling. And since 2,4,5-T is not corrosive, fewer problems in supply and treatment are encountered. However, the method does have one possible disadvantage: 2,4,5-T does not kill trees quickly. Some species are deadened within several months; others take a year or more to die. But we have observed absolutely no resprouting from properly treated 2,4,5-T frilled trees. Since this method seems to be one of the most efficient ways to poison large individual trees, some of the details of the technique are given:

A 1-percent emulsion of 2,4,5-T by weight, or its equivalent of 2 percent by volume, is easily prepared, as directed in table 1, by adding 1 gallon of a 4-pound commercial product to 50 gallons of water. The emulsion tends to settle out, and must be thoroughly agitated during preparation and at frequent intervals during use. We add a red dye--one of the concentrated wood stains--to the solution to facilitate distinction between poisoned and non-poisoned trees. This permits frill-chopping and poisoning to be done by different men, one man pouring for two to four choppers. The solution may be carried to the trees in 5-gallon back-pack cans, with gravity flow through a nozzle into the frills. The dosage is important: pour in as much as the frill will take without wasting. Two rapid trips around the tree, or one slow trip, should do the job. The method of pouring is illustrated in figure 3A. Some idea of how much chemical to pour into the frill is given in figure 4. The number

Figure 3A.--Since 2,4,5-T is non-corrosive, it can be poured into frills from ordinary metal containers. Back-pack cans, holding about a half-day's supply, are easily adapted for gravity flow.

Figure 3B.--Red oaks show a characteristic bark proliferation when treated with 2,4,5-T.

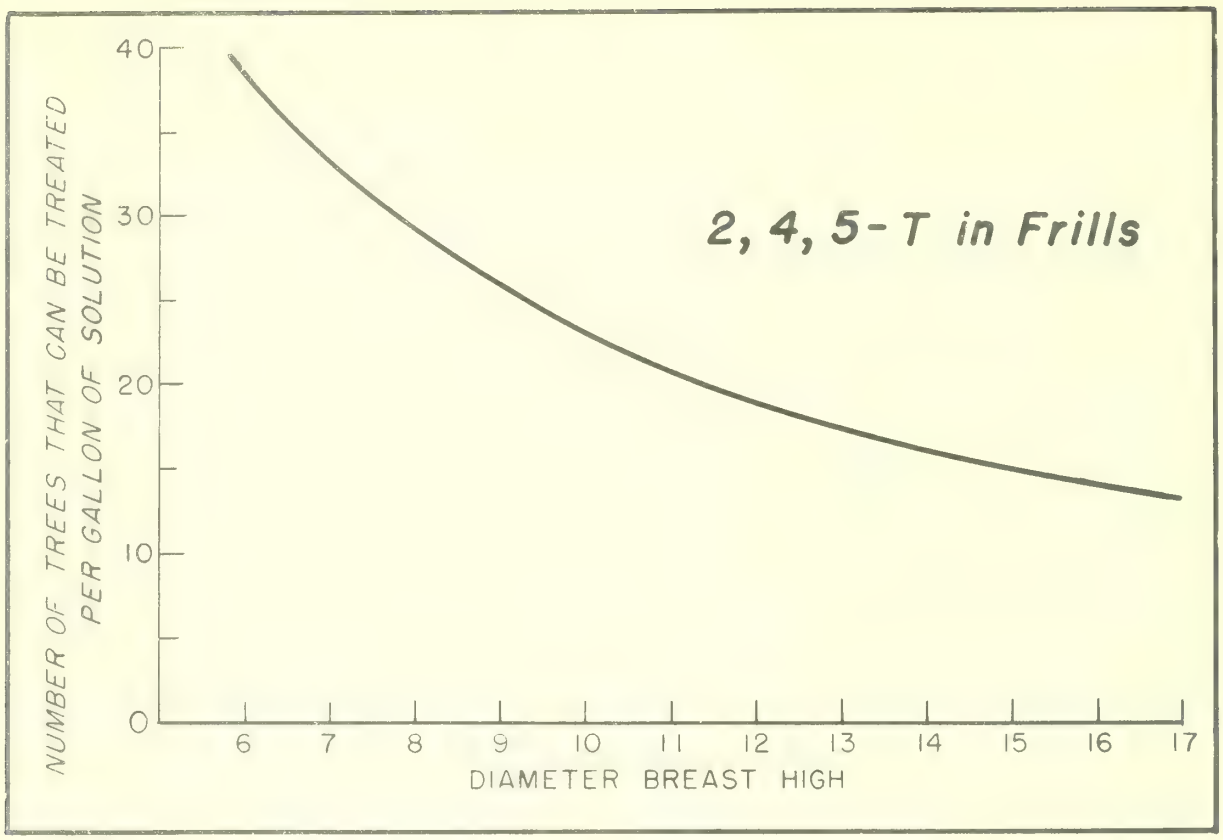

Figure 4.--One gallon of 2,4,5-T frilling solution will treat about 38 trees 6 inches d.b.h. at a chemical cost of 2/3 of a cent per tree, or 13 trees 17 inches d.b.h. at a cost of 2 cents per tree.

of trees that can be treated per gallon of solution varies from 38 trees 6 inches d.b.h. to 13 trees 17 inches d.b.h.

Among the species easily killed by 2,4,5-T in frills are those of the white oak group: live oak, post oak, white oak, and swamp chestnut oak. Some of these, especially live oak, are quite resistant to other tree poisons, and yet we find this species readily killed by even low concentrations of 2,4,5-T. The red oak group ranks next in susceptibility; among these are water, willow, and laurel oaks, and southern red

oak as well as its variety, cherrybark oak. Figure 3B shows the typical proliferation of the bark of red oaks several months after treatment with 2,4,5-T. As with Ammate in frills, beech and hickory are not killed as quickly with 2,4,5-T as are the oaks. Sweetgum and blackgum are slow to respond. However, all species that we have tested can be killed by 2,4,5-T in frills, if treated with adequate concentration and dosage.

The frill method is practical only for trees larger than 4 or 5 inches d.b.h. Smaller trees are difficult to frill properly; these may be poisoned by other methods, or simply felled without poisoning.

If we assume that a gallon of 2,4,5-T frilling solution costs 25.3 cents, we can calculate from figure 4 that the chemical cost per 6-inch tree is about 2/3 of 1 cent, and a little over 1 cent for a 10-inch tree, and almost 2 cents for a 17-inch tree. The time required for frilling and applying the chemical varies with size and spacing of the trees. In several large-scale operations, labor time for frilling, poisoning and walking between trees was 3 to 4 man-hours per 100 trees, averaging 7 to 9 inches d.b.h. Somewhat over 200 trees of this size could be poisoned per man-day of labor in stands averaging 100 trees per acre. Cost figures are less useful here than time requirements, since labor costs depend on local labor rates. However, the examples given below will serve to show how costs were divided among the different phases of the frilling and poisoning operation.

For a 24-acre block the per-acre values are:

Number of trees treated	70
Average d.b.h.	7.6"
Labor	
Chopping, 1.74 man-hours at 75¢	= $ .30
Pouring, 0.58 " " " "	= .44
Total 2.32 " " " "	= $ 1.74
Chemical	
1.60 gals. of 1% solution at 25.3¢	= .40
TOTAL COST PER ACRE	$ 2.14

The above costs represent direct costs only, and do not include overhead, supervision, transportation, equipment, or supply.

In a large test, a pulp and paper company in South Carolina reported the following costs with the use of 2,4,5 T in frills:

	370 difficult acres (per acre)	300 easier acres (per acre)	Percent of total cost
Number trees treated	155	84	
Average d.b.h. (inches)	7.1	6.1	
Labor (man hours)	5.96	4.68	
Labor (@ 85.8¢ per m.h.)	$5.98	$4.02	71
Chemical cost	$0.78	$0.54	9
Supervision, transportation, equipment, overhead	$1.82	$1.15	20
	$8.58	$5.71	100

Relative costs per tree of the frill method and other methods are given in table 2 on page 28.

The poisoning of stumps.--These chemicals have also been used on tree stumps to kill root systems and prevent resprouting. If the sole purpose is to rid the forest property of undesirable trees, there are other and cheaper ways to do it than to fell the tree and poison the stump. But if the undesired tree has a positive stumpage value--even just a few pennies--this method could be used to prevent the regrowth of the inferior species, with part or all the cost of poisoning being offset by the returns from stumpage.

For small trees, below 4 inches d.b.h., a tablespoonful of dry Ammate crystals may be placed on a V-shaped stump. This will prevent the resprouting of many species. It is usually cheaper, especially for larger stumps, to spray the top and sides with an oil solution of 2,4,5-T. A 3-percent solution, by weight (as directed in table 1, 1 gallon of a 4-pound commercial product to 20 gallons of oil carrier) will control most of the troublesome species in the Southeast. An example of the excellent control possible by this method is illustrated by figures 5A and 5B.

Although tests are under way to determine how long after cutting one might wait before poisoning, for the present it is safe practice to treat freshly-cut stumps. The technique requires that the sides as well

Figure 5A.--Stumps may be poisoned to prevent resprouting. Sprayed with 2,4,5-T in oil just after cutting, these sweetgum stumps have not sprouted after two growing seasons.

Figure 5B.--Untreated sweetgum stumps sprout vigorously, as shown by these 2-year-old sprouts, 8 feet tall.

as the top of the stumps be thoroughly wetted, to the point of solution runoff, down to the ground level.

In most deciduous tree species small stumps sprout abundantly, large stumps less so, and very large stumps only infrequently. It is well to be aware of this relationship and spray only those species and sizes that resprout vigorously. An oil-soluble dye added to the spraying solution to stain the stump top will make those treated easily distinguishable for several days.

We have only fragmentary cost data for stump sprays. The chemicals cost about 3 cents for spraying a stump 8 inches in diameter, and labor adds about 1 2 cent more.

Another use for stump sprays is in right of way construction. The cost of subsequent maintenance will be considerably reduced if all sprouting species are treated after felling. It is sprouts from stumps with large root systems that give the most trouble in right-of-way maintenance by foliage sprays.

Other cut surface methods.--Foresters trying to find cheaper ways of introducing poisons into trees have used hole-punching tools, combination hacks and sprayers, injection devices, and undoubtedly dozens of others. One of the best, the Cornell Tree Killing Tool, was developed some 2 years ago by Cope and Staeth (3). Though originally designed for use with sodium arsenite, it has recently been used with 2,4,5-T and Ammate. Our tests using 2,4,5-T are still incomplete, but reports indicate good results with Ammate at 4 to 8 pounds per gallon. The Cornell Tool, or some similar device, may provide the answer to the problem of poisoning many small tree stems, where the cost of labor, rather than the cost of chemicals, has made such spraying economically prohibitive.

Basal sprays

Alternatively called bark, stem, trunk, or dormant sprays, basal sprays consist simply of spraying a band of bark encircling the base of the tree. The chemicals presumably penetrate the bark, kill the cambium and are translocated downward and kill the roots. The simplicity of the

method, with such little manual labor involved, has captured the fancy of many foresters. Yet, of all the methods of poisoning, this is the most expensive--at least for large trees. Reasons why will be pointed out later.

Although some tree species and sizes may be killed with lower concentrations, we have found most consistent results with 3 percent 2,4,5-T in oil (acid equivalent by weight)--the same as used for stump sprays. The base of the tree must be sprayed up to a height of about 2 feet. For small trees, 1 or 2 inches d.b.h. or less, a band about 12 inches high seems adequate. For any tree, the dosage must be heavy; that is, the solution must be applied until the bark becomes saturated and the excess solution begins to run off. Figure 6 shows the method of application and figure 7 shows the effectiveness of basal sprays.

Most tree and shrub species can be killed by this method. In fact, some species, such as beech and hickory, are more easily deadened by basal sprays than by either frills or notches. It would seem logical that the thin-bark species are more susceptible to this technique, and indeed we find that, in addition to beech and hickory, other thin-bark species, such as hornbeam and southern waxmyrtle, are quickly killed. Among the thicker-bark trees, the white oak group is particularly susceptible. The red oaks can also be controlled. However, sweetgum and blackgum are slow to respond, and variable results are obtained unless quite heavy dosages are used.

Some idea of how much chemical is required to treat individual trees is given in figure 8. One gallon of 3-percent solution will treat about 14 trees 6 inches d.b.h. or three trees 17 inches d.b.h. Remember that a gallon of solution, if poured into frills, will treat about three times as many trees. This is only one of the reasons why basal sprays are more costly than frills. Others are: about two-and-one-half times as much 2,4,5-T concentrate is required to make a 3-percent basal spray solution as is used in a 1-percent frilling solution; the oil diluent used for basal sprays costs about 15 cents per gallon, while the water carrier of the frilling solution costs nothing. Add them up and we find

Figure 6.--A pressure back-pack pump is a handy gadget for basal spraying, but only about four such trees can be treated per gallon of 2,4,5-T solution. The same equipment can be used for stump spraying.

Figure 7.--Beech (A), hickory (B), and elm (C) are usually difficult to deaden; however, these species are readily killed by 2,4,5-T basal sprays.

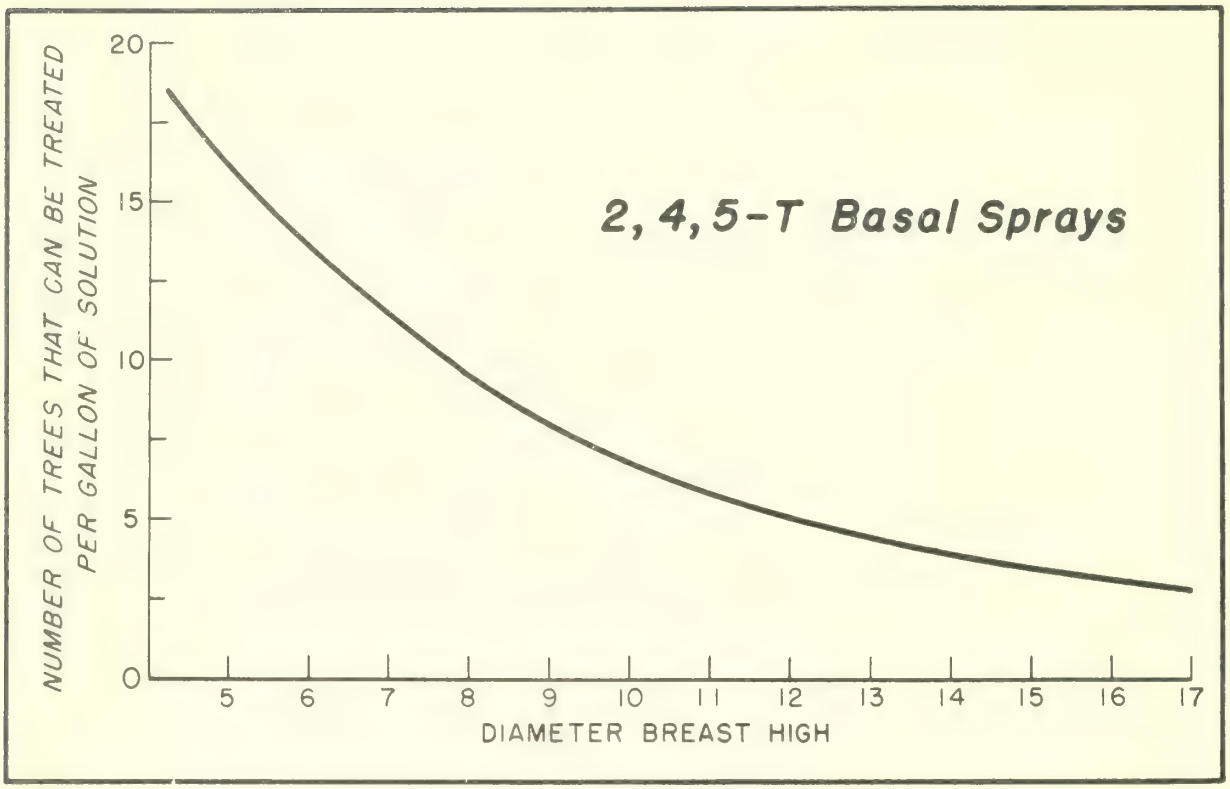

Figure 8.--Basal sprays use about three times more chemical solution than frills. One gallon of basal spray solution will treat about 14 trees 6 inches d.b.h. and only about three trees 17 inches.

that it costs about 5 cents, for chemicals alone, to kill a 6-inch tree, and about 21 cents for a 15-inch tree. For frilling, the chemicals cost a little more than 1/2 cent per 6-inch tree and about 1-1/2 cents per 15-inch tree. Thus the chemical cost of basal sprays is 10 to 15 times the cost of frills.

It is true that the labor cost of basal sprays is less than that required for frills. For example, in one test we found that the labor of chopping a frill and pouring the solution into a tree 10 inches d.b.h. consumed 1.44 man-minutes, or at 75 cents per hour, a labor cost

of 1.8 cents per tree. It took 0.40 man-minutes or 1.2 cents worth of labor to basal spray the same tree. Spraying is also easier and safer work than chopping frills.

Possibilities for lowering the cost of basal spraying by reducing the dosage or the concentration of 2,4,5-T are limited. For certain species, hornbeam, and waxmyrtle, 1 percent (acid by weight) appears to be sufficient. However, for the woods-run of species, anything less than 3 percent gave erratic results. Still another way would be to use a cheaper diluent than fuel oil. Thus far, water carriers with added penetrants have given only indifferent results. Yet we believe that further research will find ways to reduce the costs of basal sprays.

There is a good possibility that basal sprays can be used economically to poison trees too small to frill or notch. We have had excellent kill of trees averaging about 1 inch d.b.h. at a cost of less than 1/2 cent per tree for chemicals and labor. This method is also being used more and more to control brush along rights-of-way, in lieu of foliage sprays and especially for species resistant to foliage sprays.

TIME OF YEAR FOR POISONING

It is usually preferred, in the Southeast, to carry on timber stand improvement programs during the fall, winter and early spring. Labor is more readily available and can work more efficiently in hardwood brush during those months. Foliage sprays, of course, must be applied during the growing season, but the other poisoning techniques can be done at any time of the year. While it is possible that poisoning during the growing season may be more effective or require less chemical, such savings will surely be offset by the advantages of fall to spring treatments. For this reason we have designed our research for dormant season application.

Both the frill and basal spray techniques, using 2,4,5-T, kill trees rather slowly. We have observed, however, that trees are killed

more quickly if treated just prior to spring leafing. Whether or not the speed of deadening is associated with more complete kill, is still to be determined.

SOME COMPARATIVE COSTS OF POISONING METHODS

In one test, small but precisely controlled, comparative costs were extracted for several different methods of deadening large trees. The usual tree species associated with loblolly pine were represented, ranging from 5 to 25 inches d.b.h. Treatments were made on half-acre plots selected so as to be almost identical in number of trees and basal area. Costs for the several treatments are given in table 2 below.

Table 2.--Relative costs of poisoning methods compared to girdling, and costs per 10-inch tree [1/]

Method	Relative cost	Labor	Per 10-inch tree		
			Labor	Chemical	Total
	Percent	Percent	Cents	Cents	Cents
Double-hack girdle	100	100	4.8	--	4.8
Ammate notches	[illegible]	[illegible]	1.8	5.3	7.1
2,4,5-T frill	[illegible]	60	1.8	1.2	3.0
2,4,5-T basal	[illegible]	10	1.3	10.4	11.7
2,4,5-T stump	[illegible]	10	0.9	7.9	8.8

1/ Only direct costs of labor and chemical are given; all other costs are excluded. Labor is at rate of 75¢ per hour, chemicals at current cost to industrial consumer.

CHEMICALS AND PINE MANAGEMENT

Although this booklet deals principally with chemical techniques, the forest owner should remember that other methods and combinations are available. Examples of these are demonstrated on the Santee Experimental Forest, near Charleston, S. C., in loblolly pine with dense hardwood understories and cull hardwoods intermingled with the overwood. On one block the low brush was broken up with a tractor-drawn disk harrow just prior to the seedfall. Then the pine stand was cut to seed trees, and the residual cull hardwoods poisoned after logging. This area is under control and will regenerate to pine--at a direct cost of $6.12 per acre. Another block was placed under control by prescribed fire and large-cull poisoning, at a direct cost of $2.87 per acre. Still other blocks with low brush and no large culls are controlled by prescribed fire alone, or by disking. On some areas where fire or disking cannot be used because of the presence of pine reproduction, seedlings were released from the competition of heavy brush by cleaning or weeding with chemicals--at a cost of about 2 cents per released seedling.

The chemical techniques can be used to control--or, if desired, eradicate from the forest--all trees and shrubs of all species and sizes, even the pines. But not a single one will do the entire job, nor should the forester rely upon chemicals alone. Along with the other tools he commands, these chemical aids will permit the forester to solve specific problems of controlling weed species.

SUMMARY

The following suggestions are based on 5 years of experimentation in the flatwoods of South Carolina. This research is still in progress. Recommendations, therefore, are tentative and subject to revision.

Chemicals to use

2,4,5-T (the low-volatile esters of 2,4,5-Trichlorophenoxyacetic acid) is marketed as a liquid concentrate (usually containing the equivalent of 4 pounds of 2,4,5-T acid per gallon) and must be diluted for use. The diluent or the carrier may be either water or oil (such as kerosene, fuel oil, or diesel oil) depending upon the method used.

Ammate (trade name for ammonium sulfamate) is marketed and often used in the crystalline form. It may also be used in a water solution.

Both Ammate and 2,4,5-T are useful. Ammate is corrosive to metal and, while non-toxic, may cause skin irritation under prolonged contact. 2,4,5-T is neither corrosive, toxic, nor irritating. It kills vegetation more slowly than Ammate, but is often cheaper to use.

Methods of application

Foliage sprays.--Either Ammate or 2,4,5-T may be used as a water solution. This method is most useful for 1- or 2-year-old sprouts or brush up to 6 feet tall. All foliage must be sprayed to the point of runoff.

Notches or cups.--Crystalline Ammate may be placed in notches cut in the trunk at the base of the tree. The number of notches to be used equals one-half the diameter of the tree in inches at breast height. In each notch, place one rounded tablespoonful of Ammate (about 1 ounce).

Frills.--Either Ammate or 2,4,5-T, as a water solution may be poured into single-hack girdles or overlapping ax cuts encircling the tree at convenient chopping height.

Stumps.--An oil solution of 2,4,5-T may be sprayed to the point of runoff, on the tops and sides of freshly-cut stumps. Crystalline Ammate, at the rate of 1 tablespoonful per 2 inches of stump diameter, may be placed on stump tops.

Cornell tool.--High concentrations of Ammate in water solution are injected into the base of the tree. A single "jab" should be sufficient for stems 1 or 2 inches d.b.h.; larger trees require correspondingly more "jabs."

Basal sprays.--2,4,5-T in an oil solution is sprayed on a band of bark encircling the base of the tree. For stems under 2 inches d.b.h., the band should be about 12 inches wide; for larger stems, 24 inches wide.

Recommended concentration for various poisoning methods

Chemical and Method	Concentration or dosage 1/
2,4,5-T foliage sprays	1 gallon 2,4,5-T to 200 gallons water
2,4,5-T frills	1 gallon 2,4,5-T to 50 gallons water
2,4,5-T basal sprays	1 gallon 2,4,5-T to 20 gallons oil
2,4,5-T stump sprays	1 gallon 2,4,5-T to 20 gallons oil
Ammate foliage sprays	1 pound Ammate to 1 gallon water
Ammate notches	1 tablespoon Ammate crystals per notch
Ammate frills	2 pounds Ammate to 1 gallon water
Ammate-Cornell tool	6 pounds Ammate to 1 gallon water
Ammate stumps	1 tablespoon Ammate crystals per 2 inches of stump diameter

1/ Concentrations of 2,4,5-T are based on commercial products of low-volatile 2,4,5-T esters containing the equivalent of 4 pounds of 2,4,5-T acid per gallon of product.

Alternative methods of poisoning by species and sizes

(ranked in order of efficiency)

Species	Brush (under 4 ft. tall)	Small trees (1 to 4 in. d.b.h.)	Large trees (over 4 in. d.b.h.)
Sweetgum and blackgum	2,4,5-T foliage Ammate foliage 2,4,5-T basal	Ammate notches 2,4,5-T basal Ammate-Cornell 2,4,5-T stump Ammate stump	Ammate notches Ammate frill 2,4,5-T frill 2,4,5-T stump Ammate stump
White oaks and red oaks	Ammate foliage 2,4,5-T basal	Ammate notches 2,4,5-T basal Ammate-Cornell Ammate stump 2,4,5-T stump	2,4,5-T frill Ammate frill Ammate notches Ammate stump 2,4,5-T stump
Hickories and beech	2,4,5-T basal Ammate foliage	2,4,5-T basal Ammate notches Ammate-Cornell 2,4,5-T stump	2,4,5-T basal 2,4,5-T frill Ammate notches 2,4,5-T stump
Myrtle	2,4,5-T basal Ammate foliage 2,4,5-T foliage	2,4,5-T basal Ammate notches Ammate-Cornell 2,4,5-T stump Ammate stump	2,4,5-T basal Ammate notches 2,4,5-T stump Ammate stump

Season to treat

Foliage sprays must be applied during the growing season, any time between full leafing and late summer. All other poisoning techniques can be carried out at any time of the year, but are more easily applied during the dormant season.

Commercial products available [1/]

These chemicals may be purchased from local distributors of the following manufacturers:

Dow Chemical Company markets the propylene glycol butyl ether ester of 2,4,5-T as "Esteron 245."

American Chemical Paint Company markets the butoxy ethanol ester of 2,4,5-T as "Weedone 2,4,5-T."

Du Pont Chemical Company manufactures "Ammate" and also distributes the propylene glycol butyl ether ester of 2,4,5-T as "Du Pont 245T Ester Brush Killer (low volatile)."

A satisfactory water-soluble dye used for frilling solutions is: "Du Pont Wood Stain Scarlet Conc. NS," mixed at the rate of 1 pound to 200 gallons of solution.

For stump sprays, an oil-soluble dye is available from Ciba Company, as "Oil Red CY," mixed at the rate of 1 pound to 160 gallons of solution.

[1/] The list of products is presented for the convenience of users; the completeness of the list cannot be guaranteed. Listing does not imply warranty of the standard of the product to the exclusion of other products which may also be suitable.

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Forest Fire Damage Appraisal Procedures and Tables For the Northeast

by

A. W. Lindenmuth, Jr.,
J. J. Keetch,
and
Ralph M. Nelson

FOREST SERVICE

U. S. DEPARTMENT OF AGRICULTURE

Southeastern Forest Experiment Station
Asheville, North Carolina

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FOREST FIRE DAMAGE APPRAISAL PROCEDURES AND TABLES FOR THE NORTHEAST

by

A. W. LINDENMUTH, JR., J. J. KEETCH, AND RALPH M. NELSON [1/]

INTRODUCTION

Forest fire control in the Northeast is a bigger and more responsible job than most people realize. State, Federal, and other agencies currently spend some 6 millions of dollars in prevention efforts and in suppressing the 15 or 16 thousand fires that burn each year. There is good reason, therefore, to develop better and more uniform methods of damage appraisal so that the total fire bill--cost plus loss--can be determined with greater accuracy. It is only thus that the value of present and planned protection can be estimated.

Until 1951 there was no uniformity of procedure in appraising forest fire damages in the Northeast. Each State, and sometimes even districts within a State, had its own rules and scale of values. For example, the damage most frequently reported for young, satisfactorily stocked hardwood stands ranged among States from one to twenty dollars an acre (fig. 1). In some field units, a flat damage rate per acre was assessed regardless of stand conditions or fire severity. Obviously, such a wide divergence made comparisons among States, and damage statistics in general, rather meaningless. Recognizing the need for more uniformity in appraisal, the included set of provisional tables was accepted for trial by the Northeastern States beginning in 1951.

The procedures and tables presented are essentially the same as those prepared by the Southern States Forest Fire Control Chiefs' Forest Fire

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[1/] Respectively: Forester, Division of Fire Research, Southeastern Forest Experiment Station; Forester (Fire Control), Region 7; Chief, Division of Fire Research, Southeastern Forest Experiment Station.

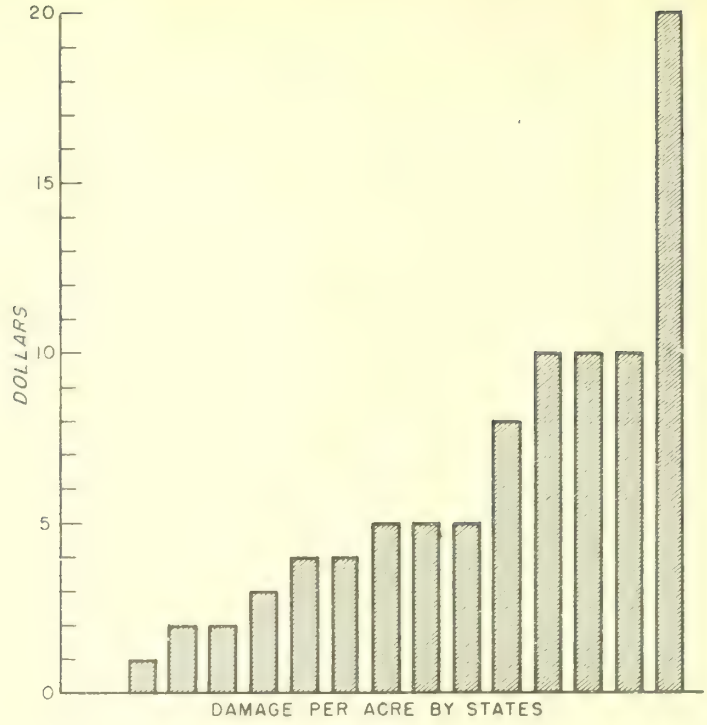


Figure 1.--Fire damage per acre to satisfactorily stocked young hardwood stands, reported by 14 Northeastern States, 1943-1949, varied widely.

Damage Committee in cooperation with the U. S. Forest Service and accepted throughout the South in 1949. The values in the present tables have been adjusted to correspond with the burning index scale on the type 5-W or 5-O meters. With this and some minor modifications, uniform methods of appraising fire damage are now used from Maine to Texas.

It is emphasized that the values in the tables were derived through the systematic use of averages--average timber stand losses and average stand values. As is the nature of averages, the figures will be reasonably accurate for large groups of fires but for a single fire may be quite unreliable.

BASIS OF FIRE DAMAGE APPRAISAL SYSTEM

Fire Damage Studies

The effects of wildfires on timber values have been studied intensively by the Southern and Southeastern Forest Experiment Stations. Their observations on some 78,000 trees on more than 340 burned areas form the basis for the present damage tables. The southern pines and principal Appalachian hardwood species are well represented in the data. From these and subsequent studies it was possible to determine the relation of tree size, species, and fire intensity to tree mortality and growth reduction. In addition, cooperative studies with the Division of Forest Pathology established the amount of butt decay that can be expected in burned stands.

Mortality is the main effect of fire on both conifers and hardwoods. Decay following wounding by fire can also cause appreciable loss in hardwoods. In fact, pitch streaks, unsound knots, or other defects caused by fire can lower the quality of mature timber in all species. On the other hand, growth reduction in both type groups is considered, on the average, to be so small that it can be ignored for damage appraisal purposes.

It is well known that under some conditions fires damage watershed, wildlife, soil, recreation, and other values. However, so little research has been done on these very complex phases of fire effects that as yet no direct monetary evaluation of them is possible. However, a flat rate of one dollar per acre has been added to all values in the tables to cover these effects.

Fire Damage Factors

In considering the factors to be used in appraising forest fire damage, a compromise between refinement and utility had to be made. Some degree of accuracy had to be sacrificed--not believed to be great on the basis of present information--to make an easily workable system. Accordingly, broad classes of forest types, tree size, and stand density, together with season of burning, and fire intensity as measured by burning index, were selected. These are variables that are significant in their effect on dollar damages; at the same time, they are easily determined in the field.

Forest type.--Only three type groups are recognized in our damage tables: pine, pine-hardwoods, and hardwoods. This may seem an over-simplification because there are five generalized types in the Northeast, namely, White-Red Pine, Spruce-Fir, Oak-Hickory, Maple-Beech-Birch, and Loblolly-Shortleaf Pine. However, no other course was possible because of the dearth of applicable information regarding fire damage in the White-Red Pine and Spruce-Fir types. Except for these two, we believe the northeastern types are adequately represented in the basic damage data.

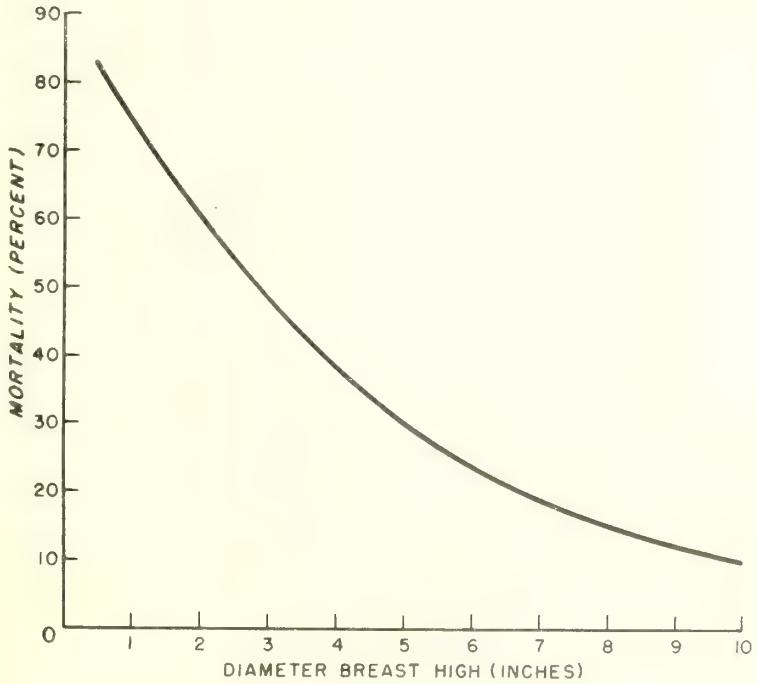
The question has been raised whether damage figures obtained from studies on southern and mid-Atlantic conifers can be applied to northern conifers. There can be no positive answer until additional research has been carried on. However, there is some evidence that the difference between the two groups is not as great as might be supposed.

The best information on this point was obtained from a comparison of our mortality figures with those obtained from a survey by the Northeastern Forest Experiment Station. Mortality in young conifer stands on more than 150,000 acres following the 1947 fires in southwest Maine differed by less than one percent from the figures on which our tables are based when the burning index was reckoned at 100. What the difference would be at other levels of fire intensity is not known, but it should not be great. Another fact revealed by the Maine survey, as will be seen from the following tabulation, is that there was little difference in seedling and sapling mortality among the pure coniferous and mixed types or in pole timber among all types, but obviously fewer small hardwoods were fire-killed.

Type	Mortality	
	Seedlings and saplings (Percent)	Poles (Percent)
White pine, spruce-fir, pitch pine, and hemlock	79	58
White pine-hardwood, and spruce-fir-hardwood	78	52
Hardwood-white pine, and hardwood-spruce-fir	76	53
Hardwood	66	56

This higher mortality rate, plus the increased susceptibility of surviving hardwoods to decay, clearly indicates the necessity for distinguishing between hardwood and coniferous types, but the data do not indicate that otherwise much refinement is warranted. They are not conclusive but are supporting evidence in favor of our original plan to use only the three type groups, pine, hardwood, and pine-hardwood. Northern coniferous types, which may not be adequately covered by this scheme, should be listed as either pine or pine-hardwood for damage appraisal purposes.

Tree size.--For all species so far as is known, the larger the tree diameter the greater the resistance to fire. This relationship in pines is graphed in figure 2. The correlation in hardwoods is also strong.



gure 2.--Mortality by diameter classes in young pine stands (burning index 65).

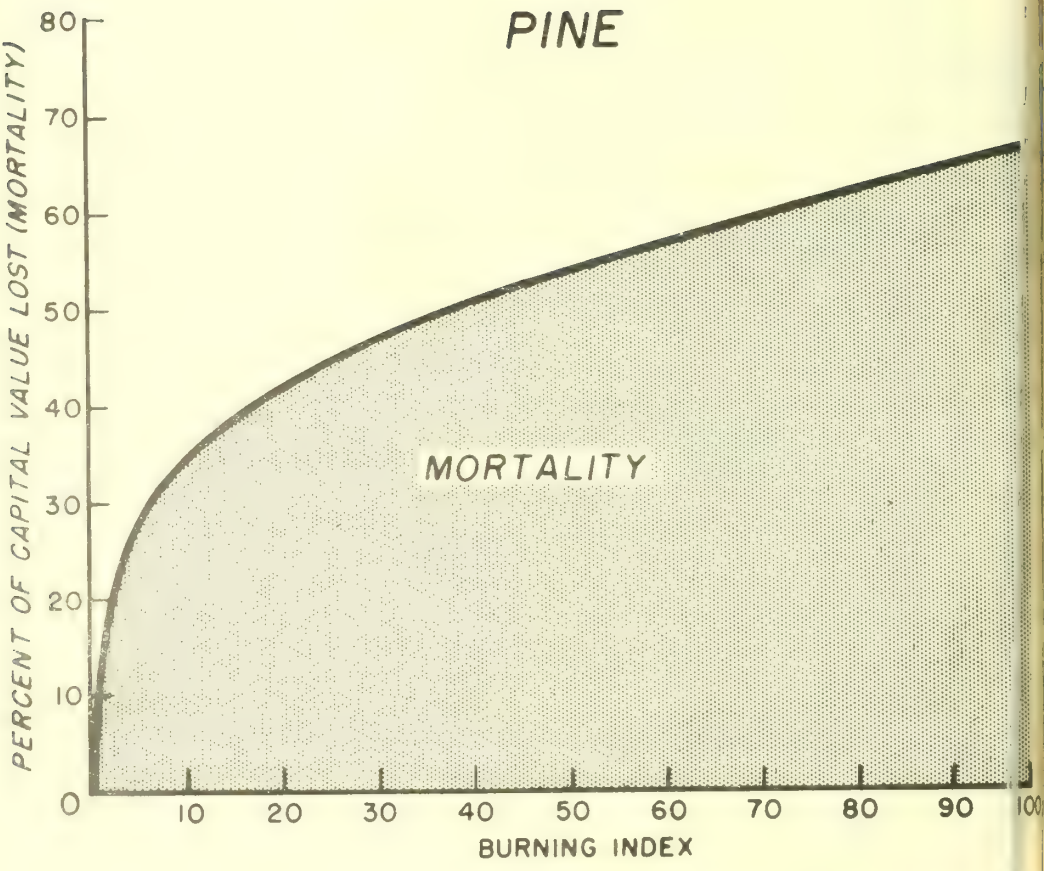
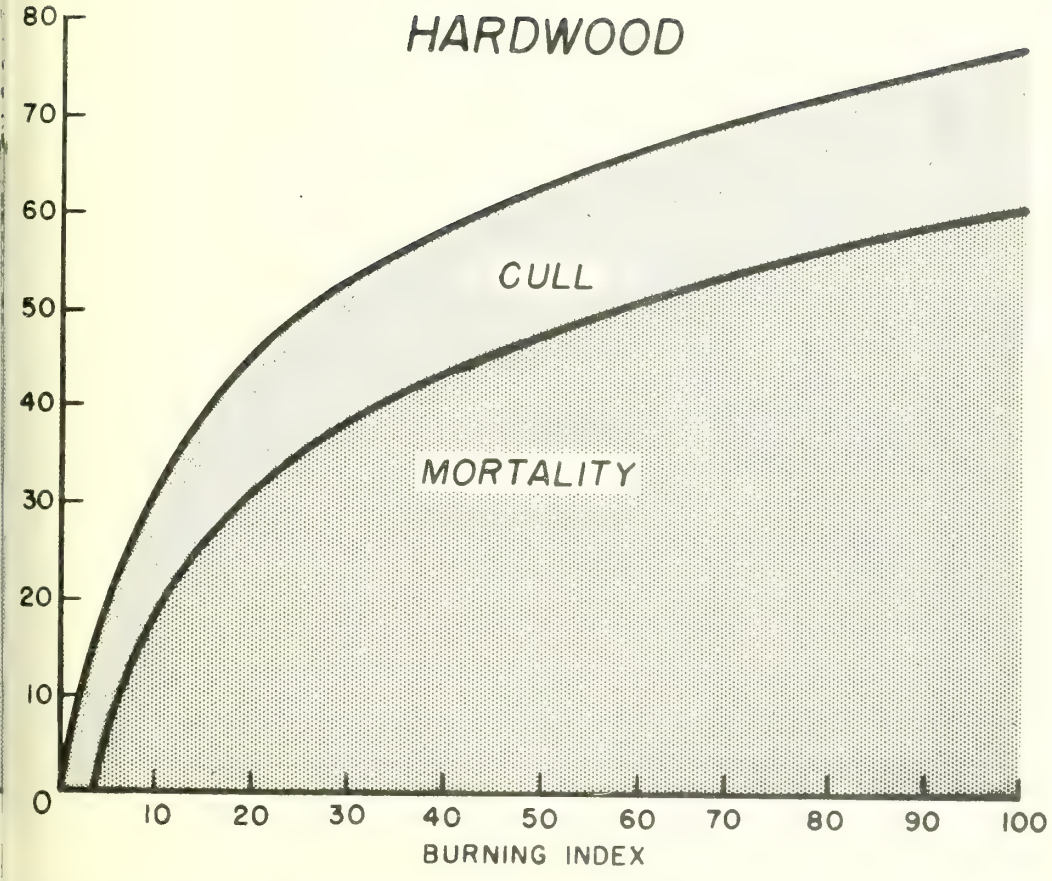


Figure 3.--Fire damage in young pine (and



ardwood stands is correlated with burning index.

For the purpose of improving accuracy of the tables, it would hav been desirable to introduce more than two diameter classes as variable in the hardwood type group. But, owing to the difficulty of classifyi typically uneven-aged hardwood stands by diameter, only two classes under 12 inches and over 12 inches d.b.h.--were recognized.

In the pine and pine-hardwood type groups, four diameter classes we included, representing roughly, reproduction, sapling, pulpwood and sa timber stages of stand development.

Stand density.--Stand density, that is, relative number of trees on unit of area, is used in this system of appraisal as one measure of t worth of the stand. By and large, stand values are directly proportion to the number of stems per acre. Volume would be a better index, b because it is difficult to measure without a good deal of experienc stand density has been used. There should be little difficulty in class fying stands into the two broad classes, satisfactory or unsatisfacto stocking.

Stand origin.--For several reasons origin has been included as one the variables in appraising damage in pine stands. On the average, plant stands, both satisfactorily and unsatisfactorily stocked, yield more th natural stands in similar categories. Also, because of the probab increase in planting in the future, as indicated by long-range forest programs, it was thought desirable to emphasize potential losses fr fire by means of a separate table. Such information may have additio value in convincing owners that plantations deserve a high degree of p tection.

Fire intensity.--Fire damage and fire intensity are obviously cor lated; the hotter the fire the greater the damage. Burning index i fairly reliable gage of intensity and is therefore used in the appra tables.

The relation between fire intensity and damage is plotted in figure Losses are expressed as a percentage of present worth, or capital va of the stand.

Season of year.--In addition to the factors already discussed, s element or elements associated with season of the year have a sign cant effect on fire losses. Generally speaking, fires do more damage i late spring, summer, and early fall than in winter. The reasons for h

easonal differences are not clearly defined, but two factors probably ccount for most of the increased summer damage. One is the general bsence of hardened bud scales and corky bark on twigs during the growing eason, and the other is higher vegetation temperatures during the summer-ime.

Unprotected plant tissue is easily damaged by extremes of either heat cold. And when vegetation is hot because of exposure in bright summer unshine, only a small heat contribution from a fire will raise the tem-erature of tissues to or beyond the lethal temperature, which is roughly 40°.

Ideally speaking, it would be best if the temperature of the individual ay could be included as a factor in damage appraisals. However, the fire anger stations are not measuring temperature. Consequently, it has been ssumed for present damage appraisal purposes that severe damage is pro-able during the season when daily mean air temperatures remain at or bove 50°, a condition favoring plant growth, and maximum daily air tem-eratures average at least 60°. As the temperature of exposed vegetation requently will exceed that of the surrounding air by about 20°, this eans that the temperature of plant tissue frequently will exceed 80° dur-g this period. On an average, the trends of the daily mean and the ily maximum temperatures are coincidental, so a single transition date n be chosen in spring and fall to denote the change of season.

Accordingly, the year has been divided into two seasons, summer and nter. An analysis of 20 years of Weather Bureau records for the North-st establishes the following transition dates for the several states d some subdivisions. Either the individual median dates (May 1 and tober 23 or 24 in Rhode Island, for example) or average dates, as stated page 19, can be used.

As a practical means of taking this average differential between sea-ns into account, damage figures for summer fires are greater than for nter by an amount equivalent to one danger class.

State	District	Daily maximum temp. of 60° or more		Mean daily temp of 50° or more	
		From	To	From	To
Virginia	Coastal	3/10	11/24	3/14	11/21
	Piedmont	3/20	11/8	3/30	11/5
	Mountain	3/29	11/4	4/3	10/30
Kentucky	Eastern	3/17	11/11	3/22	11/7
	Central	3/19	11/8	3/21	11/7
	Western	3/15	11/12	3/17	11/17
West Virginia	Southern	3/20	11/8	4/1	11/3
	Northwestern	3/30	11/5	4/4	10/29
	Northeastern	4/1	11/1	4/16	10/29
Maryland	-	4/2	11/3	4/5	11/
Delaware	-	4/1	11/4	4/4	11/
New Jersey	-	4/17	10/30	4/17	10/3
Pennsylvania	Eastern	4/15	10/25	4/23	10/2
	Western	4/17	10/24	4/29	10/2
Connecticut	-	4/27	10/25	4/27	10/2
Rhode Island	-	5/2	10/20	4/30	10/2
New York	Western	5/3	10/15	5/2	10/
	North Central	5/2	10/11	5/2	10/
	South Central	4/28	10/20	4/30	10/
	Eastern	4/30	10/18	4/29	10/
Massachusetts	-	4/30	10/20	4/29	10/3
New Hampshire	-	5/1	10/11	5/5	10/7
Vermont	-	5/2	10/8	5/9	10/7
Maine	-	5/12	10/6	5/13	10/7

BASIS OF FIRE DAMAGE VALUES

Average Yields

The yield of forests is a composite of many products. In the Northast, an evaluation of yield would include bean poles, pulpwood, fuel ood, acid wood, mine props, stave bolts, shingle and shuttle blocks, asket splints, tanbark, poles, piling, sawlogs, and a variety of other roducts. However, production varies from place to place and from time o time. Mine props, for example, are only cut in areas reasonably close o the mines, and tanbark some years is hardly merchantable, though there ave been years when entire stands were cut exclusively for bark. For ur damage appraisal tables it was therefore necessary to use average egion-wide yields of products which could be reckoned in stable units nd for which there is a universal and continuing demand. Experience has nown these to be pulpwood for conifers (the earliest merchantable product) and sawlogs for hardwoods. If the demand for immature hardwood ulpwood expands, the average yield of hardwood stands will also need to e computed in terms of pulpwood.

The average yield of northeastern forests in terms of these stable nits, and the accompanying stumpage prices in the following tabulation re thought to be reasonable averages for satisfactorily stocked stands:

Type	Origin	Age	Yield/acre	Unit value	Value/acre
Pine and pine-hardwood	Natural	20 yrs.	10 cds.	$2.00	$20.00
	Planted	20 yrs.	15 cds.	2.00	30.00
Hardwood	Natural	80 yrs.	5,700 b.f.	7.50	42.75

nsatisfactorily stocked stands are expected to yield only one-third of hese amounts.

Unit prices are assumed to be the net price after marketing costs ave been deducted.

Average Costs

The per-annum cost of producing stumpage varies widely as does th number of items entering into the cost. These are usually considered t be management expense, protection costs, taxes, administration, and inte est on investment.

Management expense.--Although some forest owners spend considerab amounts on silvicultural measures (thinning, pruning, eliminating undesi ables, etc.), these practices are not widespread. Average manageme costs on a region-wide basis are considered to be negligible and a ignored in our calculations. The same is true of administrative expense

Protection costs.--Almost all forest land in the region is protect by either State or Federal services. In addition, it is rather comm practice for timber landowners to plow and maintain firebreaks, elimina hazards, contribute time in suppressing fires, and so on, thus supplemen ing the protection furnished by public agencies. Allowance for protecti in our figures includes the average amount spent by State and Feder agencies plus the estimated average value of contributions by the landowne

Taxes.--All forest landowners who periodically harvest products p taxes in some form or other, although the amount and method of payme differ. Some pay on the basis of assessed valuation, others on the bas of the worth of products cut or sold. Because there is no good way calculating an average, what appears to be a reasonable figure (10 cen per acre per year) is used.

In summary the recognized per-annum costs per acre are:

Type	Taxes (Cents)	Protection (Cents)	Total (Cents)
Pine	10	12	22
Pine-hardwood	10	10	20
Hardwood	10	6	16

Interest Rate

A rate of 3 percent is uniformly used to discount average yields and capitalize average costs.

Stand Values

The value of immature timber stands is fixed primarily by its expected future yield and its current age. Average expected yields have been set up, and the following average ages for immature stands, determined for the most part from U. S. Forest Survey data, are used in these calculations:

Type	Size class (Inches)	Average age (Years)
Pine and pine-hardwood	0-2.0	5
	2.1-4.0	12
	4.1-10.0	20
Hardwood	0-12.0	25
	12.1+	80

The dollar-and-cents value of immature stands then can be calculated by substituting the preceding values in the following equation:

$$V = \frac{Y + E}{1.0\ p^n} - E$$

V = Value of immature stand

Y = Ultimate sale value

$E = \frac{\text{Annual expense}}{\text{Interest rate}}$

p = Interest rate

n = Number of years to reach maturity

For example, the computations for hardwoods in the 0 to 12-inch size class are:

$$V = \frac{42.75 + \left(\frac{.16}{.03}\right)}{1.03^{55}} - \left(\frac{.16}{.03}\right) = \$4.13$$

Damage Computations

The amount of damage under each category in the tables is compute from the following equation:

Damage = $1.00 + (stand value x expected loss)

For example, in the hardwood type, 0-12.0 inches size class, satisfactor stocking, burning index 65, winter season, the computations are:

Damage = $1.00 + (4.13 x 0.68) = $3.81,

or when rounded off as in our tables, $4.00.

HOW TO APPRAISE FIRE DAMAGE

The usual procedure in determining damage by this system is to (1) cla sify the timber stand burned by type, density, origin, and tree size the field and then (2) compute the loss in the office--average tabulat damage per acre times acres burned.

Ordinarily, the tabulated figures, which include average total dam to timber stands below sawlog size and damages from degrade in satisf torily stocked sawlog stands, plus a $1.00 allowance in all categor for intangible losses to soil, water, forage, and resources other t timber, are all that are needed to compute the loss from wildfires. exceptions are those fires that kill sawlog trees (not merely wound defoliate) and destroy or damage cut pulpwood, logs, fuel wood, fenc buildings, and other forest products or tangible improvements. A sep ate appraisal must be made to determine these added damages. The aver value of these supplemental losses is not included in the tables beca of the wide variation between fires; damages to improvements have b appraised as high as $20,000 on a 20-acre fire, whereas the usual fig is zero.

Classifying the Timber Stand--Field

As a general rule no plots will be measured and no tallies made when lassifying the timber stand. The warden or fire boss, while suppress- g the fire, particularly while mopping up or stepping across and around e fire to determine the area, should be able to determine the stand ndition with little difficulty or extra work.

To illustrate how a timber stand is classified, assume that an 18-acre re burned on March 15, 1951, at the intersection of Heywood and Shoal ads, Limestone Township. The town warden estimated the situation thus: tural stand, about 50 percent pine and 50 percent hardwoods, predomi- ntly pulpwood size, growing space pretty well occupied and no large enings or brushy areas, no saw timber killed and no cut forest products physical improvements damaged. So he reported this information on e Supplemental Fire Damage Report in this manner (his entries shown on e sample form on the following page):

Location-- intersection Heywood and Shoal roads, Limestone Township
Name-Number-- Limestone #46
Date of fire-- March 15, 1951
Type (page 17)-- Pine-hardwood
Origin (page 17)-- Natural
Size class (page 18) and density (page 18)--4.1-10.0 inches, satisfactory
Area burned -- 18 acres

dinarily that concludes the warden's part in appraising fire damages.

Supplemental appraisals to determine the worth of saw timber killed d cut products or improvements destroyed must be designed to fit indi- dual jobs. For instance, if a great deal of saw timber was killed over 3,000-acre area, a 10- or 20-percent cruise might be made to determine e volume killed. But if the same kill occurred on only 10 acres, pro- bly a 100-percent tally would be made. Hence, no attempt is made to tline the procedures to be followed. Stumpage and improvement values ed, of course, should be the average price currently paid in free sales r similar commodities in the community.

SUPPLEMENTAL FIRE DAMAGE REPORT

Location *Int. Heywood and Shoals Rds., Limestone Township*

Name-number *Limestone #46* Date of fire *March 15, 1951*

PINE TYPE [ ] PINE-HARDWOOD TYPE [X]

Planted [ ] Natural [X]

Size class	Density		Area Burned	Fire Intensity	Damage per Acre	Total Damage
Inches DBH	Stems per acre Less than	More than	Acres	B.I. or class	Dollars	Dollars
0-2.0	300 [ ]	300 [ ]				
2.1-4.0	200 [ ]	200 [ ]				
4.1-10.0	120 [ ]	120 [X]	18.0	(65)	(7)	(126)
10.1 plus	15 Classify young growth	15 [ ]				

HARDWOOD TYPE

0-12.0	200 [ ]	200 [ ]				
12.1 plus	15 Classify young growth	15 [ ]				
Total area burned			(18.0)			

1. Damage to young growth and intangibles, sub-total from above (126)
2. Damage or value of sawlog trees killed
3. Damage to forest products
4. Damage to improvements

Computations--Office

In addition to the stand classification, a measure of fire intensity s essential in appraising fire damage. Where fire danger is measured, in most districts, and the burning index recorded in the district office, ne dispatcher or other designated person need only enter the index in ne Fire Intensity column on the Supplemental Fire Damage Report. If nger measurements are lacking, intensity must be estimated while sup-ressing the fire and the estimate recorded as part of the field data. th the stand classified, fire intensity recorded, and knowing the sea-n of the year, the district officer can easily find the average damage r acre under the proper category in the tables and record this figure the form. Total damage, of course, is merely the product of acres and mage per acre.

In the preceding illustration, with a burning index of 65, the office tries on the Supplemental Fire Damage Report are those that are circled.

STANDARDS AND DEFINITIONS

For appraisal purposes, the area burned may be considered as a single it if it is fairly uniform; if it is not uniform, it may be divided to any number of smaller units in terms of the following definitions il standards:

1. Forest type

   a. Pine--75 to 100 percent conifers, regardless of species
   b. Hardwoods--75 to 100 percent hardwoods, regardless of species
   c. Pine-hardwood--Any mixture other than the above

   If few or no trees are evident (open land), the area should be classified as one of the three types according to the timber type surrounding the area.

2. Stand origin (method of establishment)

   a. Natural--established by natural seeding or sprouting
   b. Planted--established by direct seeding or planting

3. Size class

Classified according to the diameter breast high (4-1/2 feet abo ground) of the predominating group of trees per unit of are whether they be seedling, sapling, pole, or sawlog trees.

Description	Size class (d.b.h.)
Pine and pine-hardwood types	
Seedlings to bean poles	0 - 2.0"
Bean poles to pulpwood	2.1" - 4.0"
Pulpwood or cordwood	4.1" - 10.0"
Saw timber	10.1" plus
Hardwood type	
Seedlings, bean poles, and cordwood	0 - 12.0"
Saw timber	12.1" plus

Where two or more size classes are intermingled, only one will used. It will be the largest size class with satisfactory densi or if no size class has satisfactory density, the size class sh ing the greatest injury.

4. Stand density

Pine and pine-hardwood types: classified according to the nu of conifers per acre, other species disregarded.

Hardwood types: classified according to the number of hardwo other than weed species (sassafras, sourwood, fire cher gray birch, alder, etc.) per acre.

Satisfactory stocking: characterized by uniform tree spac few openings and no large openings, little or no grass, fer and weeds growing under the tree crowns, and the follo number or more trees per acre. The average spacing of t

in a satisfactorily stocked stand is also tabulated because sometimes it is easier to judge spacing than to estimate the number of trees.

Size class (d.b.h.)	Trees per acre (Minimum number)	Spacing (Maximum feet)
Pine and pine-hardwood types		
0 - 2.0"	300	12 x 12
2.1" - 4.0"	200	15 x 15
4.1" - 10.0"	120	20 x 20
10.1" plus	15	50 x 50
Hardwood type		
0 - 12.0"	200	15 x 15
12.1" plus	15	50 x 50

Unsatisfactory stocking: all stands not conforming to the above, including "open land."

5. Season of the year: Either the following average dates or the individual median dates, shown on page 10, may be used.

a. New England and New York

Summer: May 1 through October 15
Winter: October 16 through April 30

b. Other states

Summer: April 1 through October 30
Winter: November 1 through March 31

6. Fire intensity

County or district index for the day as integrated by the type 5-W or 5-0 meters, or, lacking danger measurements, an estimate as follows:

Light--burning indexes 0-11, mortality among seedlings an saplings one-third or less

Moderate--burning indexes 12-35, mortality one-third to or half

Severe--burning indexes 40-100, mortality over one-half

FIRE DAMAGE TABLES

Table 1: Pine-hardwood type, natural stands, fire danger measured.

Table 2: Pine-hardwood type, natural stands, fire danger estimated.

Table 3: Pine type, natural stands, fire danger measured.

Table 4: Pine type, planted stands, fire danger measured.

Table 5: Pine type, planted and natural stands, fire danger estimated.

Table 6: Hardwood type, natural stands, fire danger measured.

Table 7: Hardwood type, natural stands, fire danger estimated.

Table 1.--Forest fire damage per acre, pine-hardwood type, natural stands

SATISFACTORY DENSITY

Dollar damage per acre	Summer				Winter			
	Size class DBH (Inches)				Size class DBH (Inches)			
	0-2.0	2.1-4.0	4.1-10.0	10.1+	0-2.0	2.1-4.0	4.1-10.0	10.1
	Burning Index				Burning Index			
1							1	1
2						1	2	2-
3		1	1	1-3		2-4	3-4	4-
4		2	2	4-9	1	5-10	5-10	16-
5		3	3-4	10-75	2	11-16	11-20	50-
6		4-5	5-10	80-100	3	17-20	25-50	
7	1	6	11-20		4-6	25-30	55-100	
8	2	7-8	25-40		7-9	35-40		
9	3	9-10	45-75		10-16	45-50		
10	4-10	11-13	80-100		17-40	55-65		
11	11-100	14-17			45-100	70-80		
12		20-25				85-95		
13		30				100		
14		35-45						
15		50-100						

UNSATISFACTORY DENSITY

1						1-2	1-2	
2	1-3	1-4	1-4		1-15	3-20	3-20	
3	4-100	5-12	5-35		16-100	25-60	25-100	
4		13-25	40-100			65-100		
5		40-100						

Table 2.--Forest fire damage per acre, pine-hardwood type, natural stands

SATISFACTORY DENSITY

timated fire tensity	Summer				Winter			
	Size class DBH (Inches)				Size class DBH (Inches)			
	0-2.0	2.1-4.0	4.1-10.0	10.1+	0-2.0	2.1-4.0	4.1-10.0	10.1+
	Dollar damage per acre				Dollar damage per acre			
ght	10	6	6	4	7	4	4	3
derate	11	12	7	5	10	6	5	4
vere	11	15	9	5	11	10	7	5

UNSATISFACTORY DENSITY

ght	3	3	3	2	2	2	
derate	3	4	3	3	2	2	
vere	3	5	4	3	4	3	

Table 3.--Forest fire damage per acre, pine type, natural stands

SATISFACTORY DENSITY

Dollar damage per acre	Summer				Winter			
	Size Class DBH (Inches)				Size Class DBH (Inches)			
	0-2.0	2.1-4.0	4.1-10.0	10.1+	0-2.0	2.1-4.0	4.1-10.0	10.1
	Burning Index				Burning Index			
1							1	1
2						1-2	2-4	2-
3		1-2	1-2	1-3	1	3-10	5-13	4-
4		3-4	3-8	4-9	2	11-20	14-35	16-
5		4-6	9-25	10-75	3-5	25-35	40-100	45-
6	1	7-9	30-80	80-100	6-10	40-50		
7	2-4	10-13	85-100		11-20	55-65		
8	5-12	14-17			25-55	70-80		
9	13-35	20			60-100	85-95		
10	40-100	25-30				100		
11		35-40						
12		45-50						
13		55-60						
14		65-75						
15		80-100						

UNSATISFACTORY DENSITY

1		1			1-2	1-6	1-5	
2	1-50	2-9	1-25		3-100	7-50	6-100	
3	55-100	10-25	30-100			55-100		
4		30-65						
5		70-100						

Table 4.--Forest fire damage per acre, pine type, planted stands

SATISFACTORY DENSITY

Dollar damage per acre	Summer				Winter			
	Size class DBH (Inches)				Size class DBH (Inches)			
	0-2.0	2.1-4.0	4.1-10.0	10.1+	0-2.0	2.1-4.0	4.1-10.0	10.1+
	Burning Index				Burning Index			
1							1	1
2						1	2	2-3
3			1	1-3		2-4	3-4	4-15
4		1	2	4-9		5-9	5-11	16-40
5		2-3	3-5	10-75		10-16	12-25	45-100
6		4	6-10	80-100	1	17-20	30-50	
7		5-6	11-20		2	25-30	55-95	
8		7	25-45		3	35	100	
9		8-9	50-95		4-5	40-45		
10	1	10-11	100		6-8	50-55		
11	2	12-13			9-12	60-65		
12	3-4	14-15			13-25	70-75		
13	5-9	16-17			30-50	80-85		
14	10-20	20			55-100	90-100		
15	25-70	25						
16	75-100	30						
17		35						
18		40						
19		45						
20		50-55						
21		60-70						
22		75-85						
23		90-100						

UNSATISFACTORY DENSITY

1						1	1-2	
2		1-4	1-5		1-4	2-17	3-20	
3	1-6	5-10	6-35		5-20	20-45	25-100	
4	7-100	11-17	40-100		25-100	50-85		
5		20-35				90-100		
6		40-55						
7		60-100						

Table 5.--Forest fire damage per acre, pine type

NATURAL STANDS

SATISFACTORY DENSITY

Estimated fire intensity	Summer				Winter			
	Size class DBH (Inches)				Size class DBH (Inches)			
	0-2.0	2.1-4.0	4.1-10.0	10.1+	0-2.0	2.1-4.0	4.1-10.0	10.0
	Dollar damage per acre				Dollar damage per acre			
Light	8	5	4	4	5	3	3	3
Moderate	9	9	5	5	7	4	4	4
Severe	10	14	6	5	9	7	5	5

UNSATISFACTORY DENSITY

Light	2	2	2		2	1	1	
Moderate	2	3	2		2	2	2	
Severe	3	4	3		2	3	2	

PLANTED STANDS

SATISFACTORY DENSITY

Light	13	7	5	4	9	4	4	
Moderate	14	14	7	5	12	6	5	
Severe	15	21	9	5	14	11	7	

UNSATISFACTORY DENSITY

Light	3	3	2		3	2	2	
Moderate	4	5	3		3	3	2	
Severe	4	7	4		4	4	3	

Table 6.--Forest fire damage per acre, hardwood type, natural stands

SATISFACTORY DENSITY

Dollar damage per acre	Summer				Winter			
	Size class DBH (Inches)				Size class DBH (Inches)			
	0-2.0	2.1-4.0	4.1-10.0	10.1+	0-2.0	2.1-4.0	4.1-10.0	10.1+
	Burning Index				Burning Index			
1				1			1	1-14
[illegible]				[illegible]-[illegible]0			[illegible]-4	15-80
[illegible]				35-100			[illegible]-7	85-100
[illegible]						1-9	8-12	
		1-8	1-4		1-14	10-20	1[illegible]-17	
6	1-100	9-6[illegible]	5-12		15-100	[illegible]5-100	20-25	
7		70-100	1[illegible]-25				[illegible]0-40	
8			30-50				4[illegible]-90	
9			55-100				95-100	

UNSATISFACTORY DENSITY

1	1-100			1-100	1-7	1-4
2		1-100	1-5		8-100	5-20
3			6-30			25-85
4			35-100			90-100

Note: These revised hardwood tables are based on pulpwood yield rather than sawtimber yield as in tables 6 and 7, Station Paper No. 11, September 1951, pages 27 and 28. SIZE CLASS and DENSITY for revised hardwood tables are the same as for pine and pine hardwood types, see pages 18 and 19, Station Paper No. 11.

[illegible]--F[illegible] [illegible], ha[illegible] by [illegible]

[illegible]

[illegible]	[illegible]					
	[illegible] DBH (Inches)			[illegible] DBH (Inches)		
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]			Dollar damage per acre		
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			[illegible]	[illegible]	[illegible]

[illegible]

Light	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]

Table 6.--Forest fire damage per acre, hardwood type, natural stands

SATISFACTORY DENSITY

Dollar damage per acre	Summer				Winter			
	Size class DBH (Inches)				Size class DBH (Inches)			
	0-2.0	2.1-4.0	4.1-10.0	10.1+	0-2.0	2.1-4.0	4.1-10.0	10.1+
	Burning Index				Burning Index			
1				1			1	1-1[illegible]
[illegible]				2-10			2-4	15-80
3				35-100			5-7	85-100
[illegible]						1-9	8-12	
		1-8	1-4		1-14	10-20	13-17	
6	1-100	9-69	5-12		15-100	25-100	20-25	
7		70-100	13-25				30-40	
8			30-50				45-90	
9			55-100				95-100	

UNSATISFACTORY DENSITY

1	1-100			1-100	1-7	1-4	
2		1-100	1-5		8-100	5-20	
3			6-30			25-85	
4			35-100			90-100	

Note: These revised hardwood tables are based on pulpwood yield rather than sawtimber yield as in tables 6 and 7, Station Paper No. 11, September 1951, pages 27 and 28. SIZE CLASS and DENSITY for revised hardwood tables are the same as for pine and pine hardwood types, see pages 18 and 19, Station Paper No. 11.

[illegible]--Forest fire damage per acre, hardwood types, natural stands

SATISFACTORY DENSITY

Potential fire intensity	Timber				Timber			
	Size class DBH (Inches)				Size class DBH (Inches)			
	[illegible]	[illegible]	4.1-10.0	10.1+	0-2.0	2.1-4.0	4.1-10.0	10.1+
	All damage per acre				Dollar damage per acre			
Light	6	[illegible]	6	[illegible]	5	4	5	1
Moderate	5	6	7	[illegible]	6	5	6	[illegible]
Severe	6	6	7	5	6	6	8	2

UNSATISFACTORY DENSITY

Light	1	[illegible]	[illegible]	1	1	[illegible]
Moderate	1	[illegible]	[illegible]	1	[illegible]	2
Severe	1	[illegible]	[illegible]	1	2	3

Table 6.--Forest fire damage per acre, hardwood type, natural stands

ollar amage per acre	Summer		Winter	
	Size class DBH (Inches)		Size class DBH (Inches)	
	0-12.0	12.1 plus	0-12.0	12.1 plus
	SATISFACTORY DENSITY			
	Burning Index		Burning Index	
1		1	1-2	1-14
2	1-2	2-30	3-8	15-80
3	3-11	35-100	9-40	85-100
4	12-65		45-100	
5	70-100			
	UNSATISFACTORY DENSITY			
1	1-100		1-100	

Table 7.--Forest fire damage per acre, hardwood type, natural stands

SATISFACTORY DENSITY

Estimated fire intensity	Summer		Winter	
	Size class DBH (Inches)		Size class DBH (Inches)	
	0-12.0	12.1 plus	0-12.0	12.1 plus
	Dollar damage per acre		Dollar damage per acre	
Light	3	2	2	1
Moderate	4	2	3	2
Severe	4	3	4	2

UNSATISFACTORY DENSITY

Light	1		1	
Moderate	1		1	
Severe	1		1	

Agriculture-Asheville

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TATION PAPER NO. 12 OCTOBER 1951

A TECHNIQUE FOR HAND PLANTING OF FOREST TREES IN THE SOUTHERN APPALACHIANS

by

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U. S. Department of Agriculture

Forest Service

Southeastern Forest Experiment Station

Asheville, North Carolina

FOREWORD

This paper is not presenting a new idea. Instead, it explains the use of a planting tool and method, developed originally in Region 1 of the U.S.F.S., which seems worthy of more widespread use in other Regions; especially where planting sites are located in mountainous or hilly terrain.

The author acquired a working acquaintance with the tool during a six-and-one-half-year sojourn in Region 1, and suggested that it be given a trial in the course of planting on the Bent Creek Experimental Forest, near Asheville, N. C.

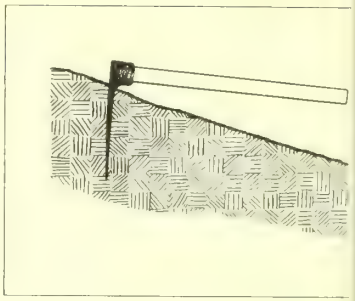
The tool and its accessory (a waterproof canvas tree-carrying bag) was accepted enthusiastically by the planting crew, and has worked out so well that we believe others will be interested in its adoption.

James F. Renshaw, Leader
Southern Appalachian Research Center

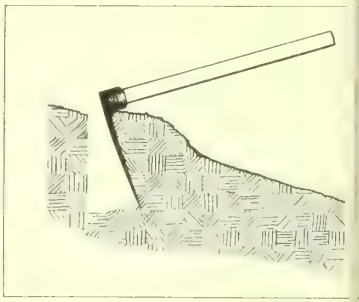
The Region 1 planting hoe and tree bag

DO

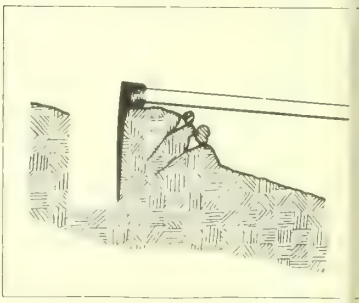
1. Grasp end of handle with right hand, raise hoe over head, and throw into the ground. Repeat once or twice more if necessary to locate favorable spot of soil.



2. Lift handle 15 to 45 degrees. (One hand is usually sufficient.)



3. Forcibly draw the handle horizontally two inches toward you. (A series of jerks with both hands may be necessary.)



4. Extract seedling from bag on left hip and with thumb and finger of left hand grasp the stem.

REASON

. To bury the blade vertically to the hilt, providing a slit of adequate depth.

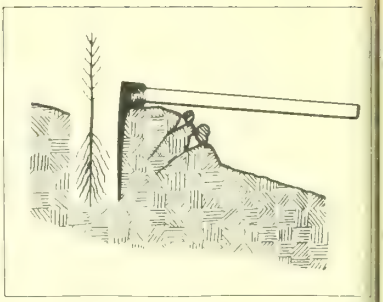
. To open the bottom of the slit and to loosen the soil mass in front of it.

. To widen the slit into a square vertical hole, eight inches deep, and clear of obstructions.

. To leave right hand free to use the hoe.

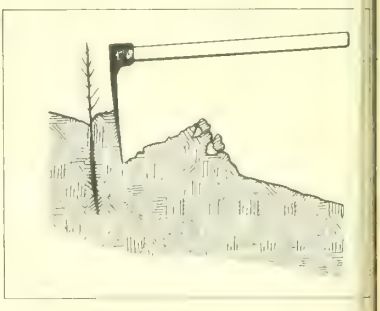
DO

5. Lower dangling roots into the hole and slightly below normal position.

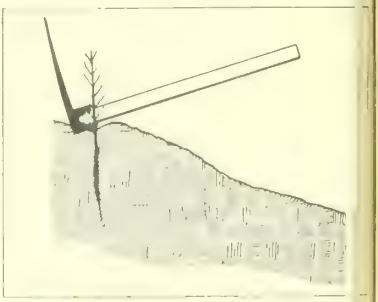


6. Raise the seedling to a position nearly the same as it had in the nursery, retaining hold until hole can be closed.

7. Jam the hole fully shut with two or more sharp blows on the loosened soil with toe of the hoe aimed at the bottom of the hole.



8. Tamp surface twice with heel of the hoe.



9. If left hand was not needed in step 2 or 3, use it now to extract the next seedling whi selecting and approaching the spot in which to plant it.

REASON

. To get natural full-depth setting for all rootlets.

. To fix the final position of roots properly deployed on back wall of the hole.

. To achieve the essential full-length firm contact with moist mineral soil for all roots.

. To pack the upper part.

. To save time through the displacement of step 4. (This may be inadvisable on a bright windy day as the exposed roots dry somewhat during steps 1 to 3 incl.)

DON'T

Don't use both hands to throw the hoe and don't attempt to retain hold of the handle.

Don't push down on the handle.

Don't wiggle the handle up and down; it is lost motion.

Don't unnecessarily expose the roots to drying by sun and wind.

Don't set them too deeply; don't bury any foliage.

Don't permit excessive distortion of root system. Avoid U or L-bends at the bottom and exposed roots at the top.

Don't tolerate excessive rocks, leaves, debris, or air space around planted roots. Scalp a badly littered surface before planting.

REASON

It is jarring and useless.

It injures the vertical back wall of the hole.

It makes a hole of the wrong shape, too wide at both top and bottom. These K-holes are narrow at half depth and interfere with step 5.

It might decrease survival.

They may be handicapped by being partly covered by shifting soil or litter.

This may lead to fungus trouble some years later and possibly loss of saplings or poles in windfall.

Trash and air space interfere with the absorption of moisture and nutrients at the critical stage when the shock of planting must be overcome.

FURTHER COMMENT
(on above listed "do" steps)

1. The planting hoe is designed as a one-hand tool. The best grip is at the end of the handle where maximum leverage is available.

2. Rock or root interference frequently necessitates a vigorous upward pull varying with the degree of obstruction.

3. If throwing has failed to bury the whole blade the planter may lean heavily on the heel of the hoe with his left hand, while wiggling the handle sideways to gain penetration. This added motion is not for loose soil, but may be expedient in stiff or root-bound soil.

4. If both hands are needed in steps 2 or 3 (or the auxiliary maneuver above) then disregard step 9, because it would mean laying the seedling down and retrieving it for step 4. Step 9 is an appropriate substitute for step 4 only in good going where everything "clicks." Then the hoe is wielded exclusively by the right hand and the seedlings by the left one.

5 and 6. Where the ends of roots, torn by the hoe project into the hole the seedling rootlets tend to be hung up. A trick of the trade is available to circumvent this difficulty. Twirl the stem a couple of revolutions between thumb and finger in step 5 to twist the root system into a narrow column. Then in step 6 reverse the twirl an equal amount to unwind the roots into normal position.

. The complete elimination of all air pockets next to the roots, always desirable, is imperative only where soil may get too dry the first year.

. This step is a good but non-essential habit. It may be replaced by stepping close to the planted seedling while advancing to the next one.

. Keep about an inch of water in bottom of the seedling bag to wet the burlap against which the roots normally rest. (A waterproof bag big enough for 200 seedlings is preferred over other types of containers.)

Inspection

he most vigilant observer cannot hope to detect ll poor planting. In fact, owing to darkness in ne bottom half of many planting holes, even the lanter himself cannot be certain of the quality f his work. Hence, all planting foremen should requently excavate seedlings to check root posi- ion and the nature of soil contact achieved. his is best done by first shearing away soil in vertical plane close to the roots, and then with n ice pick (or sharp stick) remove soil bit by it, to reveal the position and soil contact of ach rootlet planted. After resetting the plant e may wish to check his own planting in like anner.

EQUIPMENT

Further information concerning the planting hoe and tree bag may be obtained from the Southeastern Forest Experiment Station, Box 252, Asheville, N. C.

A similar tool is manufactured by the Council Tool Company of Wananish, N. C., and may be used as described herein by cutting the handle back to 18 inches in length.

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STATION PAPER NO. 13

NOVEMBER 1951

FOREST RESEARCH IN THE SOUTHEAST

by

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U. S. DEPARTMENT OF AGRICULTURE FOREST SERVICE

Territory of the Southeastern Forest Experiment Station.

FOREST RESEARCH IN THE SOUTHEAST[1/]

by E. L. Demmon, Director
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Asheville, N. C.

INTRODUCTION

As most of you probably know, the salient fact for foresters or other natural scientists in the Southeast is the division of the region into three distinct provinces. They are: the Blue Ridge and Great Smoky Mountains comprising the south end of the Appalachian range; the Piedmont, which rolls away for about a hundred miles at the foot of the mountains; and last, the sandy, level coastal plain, wet and laced with tidal streams. These three provinces have different climates, different soils, different tree species, and even rather different people. The Piedmont is the place where King Cotton used to rule. But he has bowed out, and the gullied fields, by the millions of acres, are being handed over to the forester, who always gets the leavings, doesn't he? The Coastal Plain boasts the fastest pine growth of any region in the country; with long growing seasons and plenty of rain, the crescent-shaped pine belt extending from Virginia to East Texas is the great reservoir of raw material for the southern pulp and paper industry. As for the mountain region, it is the former home of what were perhaps the finest hardwood forests in the world--now severely high-graded and producing but a fraction of the oak, yellow-poplar, basswood, ash, walnut, maple, birch, cherry, and white pine that would be possible under good management. The mountain, too, is the great water storage reservoir for cities and industries that may be hundreds of miles away.

The five Southeastern states from Virginia to Florida contain a very sizeable part of the Nation's forest wealth. Commercial forests of the Southeast (covering 86 million acres, or 58 percent of the total land area of 149 million acres) represent 20 percent of the total for the United States. Its forest industries include between 12,000 and 13,000 sawmills, 30 pulp mills (with 5 additional ones under construction), and more than a thousand units of secondary forest industries.

To serve this varied region, the Forest Service has for 30 years maintained a research headquarters at Asheville, N. C. This is the Southeastern Forest Experiment Station. Its field studies are concentrated at eight research centers located in various parts of its territory. These centers were selected as typical of the forest conditions in a section, so that the results of field studies will be applicable to wide areas or broad forest types.

1/ Paper presented at the 29th Annual Meeting of the Association of State Foresters, Charleston, S. C., October 3, 1951.

The Station is set up to serve the timberland owners of the Southeast. Its customers include the national forests (5 percent of the commercial forest land ownership); state and other public forests (3 percent); and the private landowners (92 percent), of which farmers own 44 percent and other private owners 48 percent of the total. The lumber industry still continues to be the principal user of the southeastern forests (accounting for about 50 percent of the total drain on the forest), but the pulp and paper industry has expanded greatly in recent years, now owning about 7 million acres of forest land and using at least 20 percent of all the wood harvested in this region each year.

Much of the Station's program is carried out in cooperation with state forestry departments, with schools of forestry, and with the forest industries. Its program at the various centers is reviewed periodically by local advisory councils representative of local forest landowners and forest users. The results of Station studies appear in numerous station papers, technical notes, annual reports, Government bulletins, and in professional and trade journal articles. Its experimental forests serve as demonstration areas to illustrate various types of forest and range management. The Station also works closely with forest pathologists, entomologists, and biologists from other bureaus.

In this short discussion, it will not be possible to report on all of the Station's many activities. I will attempt, however, to give a few examples of how research is helping point the way towards better forest management and better land use in the Southeast.

FOREST MANAGEMENT

The largest share of the Station's work is forest management research. In this field, the major single project is a long-time research comparison of the forest management systems which may be applicable to each major forest type. On each of six different experimental forests in various parts of the region, this project includes a great many 40-acre compartments on which are applied different silvicultural systems, usually comparing two rotations, and two intensities of forest management: (1) for small-sized products such as pulpwood and (2) large-sized products such as veneer logs and sawlogs. In addition to the long-time purposes for which they were set up, these compartments are invaluable in providing conditions for detailed studies of individual silvicultural problems.

Following are several examples of Station findings in the forest management field during the past few years:

New Methods of Naval Stores Gum Production

One of the most concrete examples of the contributions of forest research in the Southeast comes from the Lake City, Florida, Branch where

new techniques for gum naval stores (turpentine and rosin) production have been developed. When I first came to the South in 1925, naval stores gum production was a relatively crude and wasteful process that left millions of small worked-out trees each year to burn or blow over before they reached saw-log size. Deep chipping of second-growth trees yielded a meager return to the gum producer for the amount of labor required. Due to research and to the changing times, naval stores practices have radically changed during the last 25 years. The Station has found that nearly half of the chipping labor can be saved with no loss in gum yield by spraying sulfuric acid on the fresh cut to prolong the flow of gum. Here is an instance where the Russians apparently can make a bona fide claim to an initial basic discovery, but the perfection of the technique and its application to United States conditions was worked out at Lake City, Florida. It is estimated that this one research development will save the naval stores industry about a million dollars in 1951 when applied to about one-fourth of the producing trees. If it were used throughout the industry, it would save a million man days of labor each year. This is all the more important when it is realized that during past emergencies, naval stores production has dropped below industrial needs through labor moving to better paying industries.

During the research on acid treatment, it was found that chipping into the wood was unnecessary if acid was applied. The Station developed a new type of chipping tool which removes only a strip of bark, and leaves the bole of the tree round. If these round butts are freed of nails and harvested promptly, they are practically as good as the butts of untapped trees for pulp and other wood products.

Paralleling research on turpentining methods, the Station is cooperating with the University of Florida in the development of new equipment for gum production. Station personnel invented a remarkably simple and effective acid sprayer resembling the soft plastic sprayers now used for perfume and other products. This squeeze sprayer has also been built into a combination chipping and spraying tool.

The natural rubber industry, in which I worked for a number of years, has made great technological strides through the application of genetics in developing high-yielding strains of Hevea rubber trees. We can use this as an example of what might be done for the naval stores industry. A small-scale start has already been made in developing high-yielding strains of longleaf and slash pines. We now have at Lake City cross-bred seedlings six years old and rooted cuttings over 20 feet tall, grown from selected parent slash pines that yielded twice as much gum as average trees of the same size. Interest in the whole field of the genetic improvement of southern pines is awakening, and a regional committee on Southern Forest Tree Improvement has been set up. Though forest planting now exceeds two hundred million seedlings a year in the South, we know all too little about the importance of seed source, and much less about selection and breeding of superior strains.

Chemical Control of Hardwoods

There is perhaps no more important forestry problem in the Southeast than that created by the rapid encroachment of hardwoods into the valuable loblolly pine stands of the Piedmont and Coastal Plain. In South Carolina, for example, the forest survey found that the hardwood area increased by 59 percent between 1936 and 1946. The major research job here is to develop economical ways for controlling inferior hardwoods on pine sites.

The Station's studies of this problem have been centralized at our Central Coastal Plain research center at Charleston, S. C. After testing numerous chemicals, concentrations, and dosages on different tree species by different methods and at various seasons of the year, our men have worked out several practical poisoning techniques. A new Station publication just off the press summarizes this information in convenient form for the forest landowners of this region ("The Use of Chemicals to Control Inferior Trees in the Management of Loblolly Pine," by L. E. Chaiken, Station Paper No. 10, September 1951). Undoubtedly, these findings are also applicable in many localities outside this region.

Our branch at Charleston is also working on the role of prescribed fire for the control of hardwoods. Eventually, increased utilization of these poorer quality or slower growing hardwoods will help ease this problem, but in the meantime, timber growers can benefit from hardwood control measures.

Methods for Reproducing Loblolly Pine

Nature had a much easier job of seeding in good stands of loblolly pine on old fields than we have now in reproducing these same stands. One of the difficulties of obtaining full restocking to pine is the competition of small hardwoods, but another is shortage of pine seed, particularly when stands are cut on short rotations. Some research has been done on this problem at Duke University and at the Station's research center at Franklin, Va., where there are many well-stocked loblolly pine stands ready to harvest. Station studies have shown that from 20 to 37 thousand pine seeds per acre from a single seed crop are required to insure adequate restocking where the seedbed is favorable. The average number of seeds needed to produce one established seedling varies from 83 on a slash-covered seedbed to 7 on exposed mineral soil. Seed dispersal is effective to a distance equal to about twice the height of the seed trees. Also, it has been found that pre-harvest release of seed trees to a distance about equal to the crown diameter stimulates seed production. In the third year following such release, loblolly pines usually produce several times more seed than similar unreleased trees.

A method has been worked out for predicting loblolly pine seed crops six months to a year in advance. From information on the size of the current year's seed crop, and the ratio of number of cones in the current crop to next year's crop, a good approximation of the size of the next seed crop can

be computed. This type of information is particularly valuable in planning for seed collection and for regeneration cuttings. Also, it is extremely important to harvest mature loblolly in a good seed year and get prompt regeneration before the hardwood understory takes over.

Farm Woodland Management

The biggest opportunity for improving forest land management in the Southeast rests with the 3/4 million small landowners (a majority of them farmers) who own two-thirds of all the commercial forest land. Much of the Station's forest management research applies to farm woodlands in one way or another. However, the farmer works under a unique set of conditions with respect to labor supply, equipment, home-use requirements, markets, and the timing of his income. Experience has shown the desirability of setting up on our research areas one or more test woodlots where silvicultural and management information is readily available to farmers through field-day demonstrations or otherwise. I know that all of you must have seen published reports on the income possibilities shown by these experimental farm forestry woodlots.

FIRE

The Southeast still has a long way to go in securing adequate fire protection. In 1950, 14.8 million acres or 17 percent of its entire forest area still lacked protection. During that year 90,191 fires occurred, burning over 8-1/2 million acres of forest land. It is recognized that 1950 was a relatively severe fire year for the Southeast, due to an extended dry fire season, so the fire record was worse than for the previous few years. One percent of the fires were started by lightning; the balance were man-caused, the major source (43 percent of total) being incendiarism.

Fire statistics for calendar year 1950 on all forest land in the five Southeastern States

State	Area needing protection	Area protected		Total fires	Area burned	Protected area burned	Total expenditures
	Million acres	Million acres	Percent	No.	Thousand acres	Percent	Thousand dollars
Va.	14.6	14.6	100	2,110	21	0.14	575
N. C.	18.4	16.6	90	4,357	485	2.79	1,581
S. C.	11.9	11.9	100	8,190	239	2.01	1,280
Ga.	21.0	15.0	71	43,284	2,944	2.01	776
Fla.	21.2	14.2	67	32,250	4,818	2.87	835
Total	87.1	72.3	83	90,191	8,507	2.00	5,047

There are two main projects in the Station's fire research program. The first concerns developing improved methods of measuring fire danger and applying danger measurements to fire control planning. At present there are more than 500 fire danger stations from Maine to Texas using methods developed by the Station.

In addition to the day-to-day use, fire danger measurements have been found valuable in long-range fire control planning. In the Northeast, because of the continuity of good fire records furnished by the States, it has been possible to determine trends in fire occurrence. A strong relationship has been found between number of fires and measured fire danger. On the basis of measured danger, we can now predict for a district, state, or region, the number of fires likely to occur during this month or this year. By studying monthly or yearly trends, fire control officers can now get a reliable comparison between one year's record and another or between districts.

In the past when the number of fires decreased below previous years, the tendency has been to credit the reduction to greater effectiveness of the fire organization. When the number of fires increased, the tendency was to blame it on the weather. What research has done is to take out some of the guesswork, so that administrators can better judge the effectiveness of their organizations.

Another use of fire danger measurements is through adding up the daily readings. This makes it possible to follow closely the build-up of danger in a district and to take special precautions, such as closure, when conditions are especially threatening.

The second main fire project at the Station is the study of fire behavior, both for wild fires and for prescribed burning. Most of this work has been done on the Francis Marion National Forest, near Charleston, S. C. It is important to know the conditions of fuel and weather when prescribed burning can be done to obtain the desired effect.

Fire is now recognized as a valuable tool in the management of southern pines. It can be used for the control of brownspot disease in longleaf pine seedlings, as well as for hazard reduction, seedbed preparation, reducing hardwood competition, and for improving forage conditions and wildlife habitats. When properly used, fire can serve all of these purposes with very little or no damage to the stand. However, there are cases where severe damage has resulted when prescribed fires burned with greater intensity than was intended. We still do not know nearly as much as we should about when to burn and how to burn.

One Station study has revealed that in grassy fuels headfires are cooler near the ground than backfires. This means that when burning for brownspot control of longleaf pine seedlings, for example, and when there is little chance of damaging the overstory, headfires will do less harm than backfires. It is, of course, possible to burn a much larger area with a headfire than with a backfire in the same length of time, which means lower

costs. Also, because there may be but few good burning days during the season, the faster the prescribed burning can be done the better.

Another Station finding is that vegetation temperature greatly influences the effect of fire. For example, on a cold day when the temperature is around 40° a pine tree can tolerate a fire 2-1/2 times as intense as on a day when the temperature is near 100°. This is of practical significance in prescribed burning. On the Francis Marion National Forest undesirable hardwoods 3 and 4 inches in diameter have been killed with summer fires. Conversely, in pine reproduction stands, less damage will result if burning is done on a cold day in winter.

A phase of our fire behavior work that shows great promise is the study of erratic fire behavior. Every experienced fire fighter knows that at times fire will behave in a way that cannot be explained on the basis of fuel or weather; that they will crown and spot unpredictably. Such "blow-up" fires have occurred in every region but have been particularly severe in the West.

In the spring of 1950, in the Coastal Plain region, there were a few days when fires behaved in a very unusual way. Although winds were light or moderate, fire fighters could observe no reason why large whirlwinds in the fires sometimes developed, and fires crowned and spotted. Fire research technicians suspected that atmospheric phenomena might account for this behavior. Radiosonde records (by releasing balloons) from the U. S. Weather Bureau in Charleston showed that on those days there was a highly unstable layer of air 300 to 500 feet above ground. Although undoubtedly certain combinations of fuel, stand density, and size of fire are contributing factors, it seems likely that the explosive qualities of these 1950 spring fires were related in some way to rapid changes of temperature in the lower 1,000 feet of air. Perhaps we are now on the track of a major factor causing "blow-up" fires. Perhaps a way can be found to predict days of high atmospheric turbulence. At any rate, the Station plans to study this subject as intensively as we can with present facilities. Such studies can well be carried on in the Flatwoods region because here there is no confounding effect of topography.

WATER

Water and watershed protection were the major reason for establishing national forests in the East--as the Weeks Law makes plain. But in those early years, it was timber that paid off in cold cash and timber that foresters were principally concerned with. Now the pendulum is swinging again; water becomes more valuable every year, and there are times and places where it is already priceless. The rapid expansion of industries and municipalities in the Southeast is bringing a realization that even here there is a limit to available water supplies. Just where this limit will lie depends in large part on the management of the 60 percent of the

South-east that is forest land, for the forests are in effect huge detention reservoirs, vaster than any Grand Coulee that man has ever made. Foresters are beginning to have it impressed upon them that water may be the most valuable product of the mountain forests. Also, we foresters must recognize that we have a responsibility for the production of water as well as timber.

The Southeastern Station has under way a research program in water resource management at two work centers. The Coweeta Hydrologic Laboratory, a watershed covering 5,400 acres in the high rainfall belt of the mountains of Western North Carolina, is one of these. Here, since 1933, the Station has been working out ways and means of integrating water yields with uses of the land for the production of timber, forage, fish and wildlife, and for recreation. For example, the effect of clearing steep forest land for farming has been measured by actually carrying out each step of the process on a carefully gaged experimental watershed. Similarly, studies are being made of the effect of woodland grazing, of fire, and of logging on water quality and yield. These studies have shown that any damage to the forest soil is unfavorable to good watershed management. In the past, foresters have usually failed to recognize the inconspicuous early stages of changes in soil structure that ultimately result in severe damage to the water resource.

In addition to the land-use approach, the Station has studied some of the fundamental effects of the relation of trees to stream flow. Such basic considerations have included the measurement of the amount of rain intercepted by tree crowns and evaporated back into the air. Few realize that in a 40-inch annual rainfall area, only about 32 inches actually reach the forest floor during the year; the other 8 inches, or 20 percent, is caught by the tree canopies and evaporated. The tree roots, therefore, have only 32 inches of rain water available instead of the 40 inches as measured in the open. Measurements are also made of moisture and ground water stored in the soil at different seasons of the year, and their rate of withdrawal from storage through transpiration and as runoff in streams.

At the Calhoun Experimental Forest in the Central Piedmont of South Carolina, the objective is to determine the place of forests and forestry practices in maintaining or restoring soil and water resources. Measurements are being taken of soil and climatic factors to better rebuild worn-out land through practical forestry measures. We have already worked out some of the effects of litter from different forest stands in adding nutrients to the soil. Hardwood litter adds more calcium and nitrogen to the soil than does pure pine litter. These studies have also indicated that moisture conditions for plant growth are extremely unfavorable on the depleted and abandoned cotton fields now constituting the principal sources of erosion and flood in the Southeast.

It is apparent that unfavorable soil-water relations play a major role in the occurrence of the littleleaf disease. As the soil structure improves over the years and as conditions more nearly approach those of

the original virgin forest, some of the factors predisposing to littleleaf may gradually disappear.

There are many problems related to water control and management where further research is needed. One such study would determine the effect of the height of the water table on tree growth in the Coastal Plain and Flatwoods region. It is possible that heavy harvest cuttings may result in a permanent rise of the water table. There is ample evidence in some localities that sites which once produced good saw-timber stands have changed to sedge and swampland. Drainage of forest land is another problem that needs investigation. Many drainage projects are now under way, but what effect they will have on tree growth is not yet known.

FOREST SURVEY

Since 1946 the Forest Survey, with help from the South Carolina State Commission of Forestry and the Florida Forest Service, has completed the second survey of the timber resources of both South Carolina and Florida. A similar resurvey is now under way in Georgia, and it is planned to start work soon in North Carolina in cooperation with the North Carolina Department of Conservation and Development.

These resurveys clearly show what is happening to a State's forest resources. In South Carolina, for example, the volume of saw timber decreased 10 percent between the time of the first survey in 1936 and the resurvey of 1946; the volume of all timber 5.0 inches d.b.h. and larger decreased by five percent. In the southern part of the Coastal Plain, the decline was substantially greater. In the face of this, South Carolina forest industries have been expanding. Total timber drain increased from four million cords in 1936 to five million in 1946, and no easing of the pressure for timber is in sight. In 1950 the pulpwood cut alone amounted to 1,182,000 cords, 16 percent more than in 1946.

The Survey has found many of the reasons why timber yields have not kept pace with growing demands for timber. A decline in the amount of forest land is not one of them, as the forest area of South Carolina increased by 1.2 million acres during the 10 years between the two surveys. Instead, we find that 4.5 million acres of forest land, out of a total of 11.9, are poorly stocked and are not growing very much timber. Also, 20 percent of the total woodland area is overstocked with trees and should be thinned to increase growth.

The quality of the timber has also declined. Now, one tree in five is a cull, compared to one tree in ten in 1936. The cull tree volume, which was only 11 percent of the total in 1936, increased to 18 percent of the total volume in 1946. Practically all of this cull volume is in hardwoods.

Along with the increase in cull hardwoods, there has been a 1.7 million-acre increase in the acreage of hardwood types. In the Sandhills, scrub oaks took over more than 400,000 acres, and in both the Piedmont and Coastal Plain, heavy cutting of pine allowed hardwoods to increase. This threatens future usable timber supplies, as a high proportion of these hardwoods are of low quality.

The amount of forest growing stock is now considerably less than is needed to provide the annual timber needs of industry. Saw timber is deficient over all of South Carolina, and young trees below saw-timber size are particularly scarce in the Coastal Plain. Only in the Piedmont is there a surplus of young timber.

These highlights of the forest situation in South Carolina provide the basis for planning a forestry program aimed at improving forest conditions within the state. Similar surveys at about 10-year intervals should provide accurate information for planning state forestry programs and the basis for industrial development on a sound scale.

FOREST GRAZING

Research in forest grazing, in cooperation with Federal and state agencies, is being carried on in the Southeastern coastal plain pineries--principally in the states of North Carolina and Georgia. Much has been learned about the natural forage value of the most promising vegetation types, as to quality and quantity of forage produced, effects of fire on forage values, occurrence of poison plants, and the value of supplemental feeding. Current studies have to do with methods of integrating cattle and timber production, methods of forest range improvement, and increasing grazing capacity. One Station finding indicates that switch cane areas of North Carolina may have the highest grazing capacity of any native range in the United States today.

FOREST UTILIZATION SERVICE

The Station's Forest Utilization Service project represents a connecting link between the Forest Products Laboratory at Madison, Wisconsin, and the wood-using industries of the Southeast. The Forest Utilization Service men have been mainly concerned with how to reduce wood waste, how to use more low-grade wood and little-used tree species, and how to improve the use of the declining supplies of high-quality raw material. Among other things they have designed an automatic wood-burning furnace for curing bright-leaf tobacco, which enables farmers to utilize home-grown, low-grade wood as fuel, and at the same time improve their woodlands.

The Station has also stimulated a program of research at the Forest Products Laboratory to find additional uses for hickory, much of which is now left in the woods because it does not meet the standard for products such as skis, picker sticks, and handles. However, our studies in cooperation with private concerns show that by improved drying methods to reduce checking, some of this low-grade hickory can be used for cross ties. Also, it has been found possible to laminate hickory with ash for baseball bats.

Improvements in air-drying and kiln-drying practices in furniture manufacture have resulted from courses in drying techniques arranged by the Station. Similar courses have been arranged to show improved techniques in gluing wood. Many requests for advice and guidance in the field of wood utilization have been met by Station technicians. At present, we are completing the development of simplified log and tree grades for southern pine, in cooperation with the Southern Station and Region 8 of the Forest Service. These grades should improve marketing practices and help channel high-quality raw material into products requiring the highest grades for manufacture.

CONCLUSION

Forest research in the Southeast is providing information of value to landowners in obtaining better forest management. However, the Station is still unable to work on many important regional problems due to lack of sufficient facilities and technical manpower. Among the areas of the Southeast where the Station has not yet been able to undertake a real research program are the northern Piedmont belt, the sand hills of North and South Carolina and Georgia, the slash pine and cypress areas in South Florida, and in the bottomland hardwood and pond pine types.

State foresters are and should be among the foremost customers of forest research. State foresters in this region have always taken a keen interest in the Station's work, have used our findings widely, and in many instances have contributed manpower and other facilities to furthering research. This has been particularly true of the forest survey, the results of which are immediately useful for many purposes such as in plans for the expansion of forest industries. Undoubtedly, there are many other ways in which state foresters can use the Station's facilities to greater advantage. I have in mind the opportunity offered by the Station's research centers and experimental forests for state personnel training purposes.

I think I speak for all forest experiment station directors in saying that we are anxious to keep Station programs oriented to help solve your pressing technical forestry problems. To this end we welcome constructive criticisms and suggestions concerning our programs. We also welcome your support for our work and your assistance in getting research findings applied in woods practices. We want you to feel that these are your stations and that your problems and ours are mutual. With a combined attack on these problems, American forestry should make more rapid strides than ever before, to the social and economic betterment of our country.

TATION PAPER NO. 14 JANUARY 1952

OBSERVATIONS ON HEAT TOLERANCE of Southern Pine Needles

by

Ralph M. Nelson

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U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE

OBSERVATIONS ON HEAT TOLERANCE OF SOUTHERN PINE NEEDLES

by

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When forest fires burn through southern pine stands, effects on tree crowns range from no observable injury to complete browning and even total consumption of all needles. Mortality and loss of growth that may follow are largely determined by the extent of damage to the foliage, particularly to the buds and twigs. Height of scorch line, as marked by yellowing or browning needles, is a rough measure of damage.

Four major interacting elements determine whether pine needles are damaged by fire. These are fire intensity, initial vegetation temperature, length of exposure to heat, and lethal temperature of needles. Fire intensity varies according to fuel, weather, and rate of spread. Initial vegetation temperature is highly significant because a tree crown on a cold day at a temperature of 40° F. requires about two-and-one-half times as much heat to reach a lethal temperature as does a crown on a hot sunny day at 100° F. Duration of heat is also a significant variable because the longer needles are exposed to heat the more likely they are to be killed. For example, it can be assumed that a fast-burning headfire which may subject foliage to heat for only a fraction of a minute will cause less damage than a slow-burning backfire of equal intensity which may take several minutes to pass a given point. Finally, the degree of ability of cells within pine needles to tolerate heat has a direct bearing on the extent of foliar injury.

The purpose of the study reported here was to determine some of the time-temperature relations as they affect the death of pine needles. The study is one phase of a project designed to provide information on fire behavior, intensity, and effects which will be helpful in prescribed burning and damage appraisal.

RESULTS OF OTHER WORKERS

Although considerable investigation has been made of the heat tolerance of northern and western conifer seedlings, little information was found that would give more than a general clue to the lethal temperature for pine needles. Bates and Roeser (2) report that seedlings of the western conifers tested suffered critical injury when exposed to a temperature of 141° F. (about 60° C.) for one minute. Baker (1) found that 1- to 3-month seedlings of representative conifers of western America were quickly killed when subjected to a temperature of 54° C. but could withstand a temperature only a few degrees lower for some time. Shirley (4) states that the maximum temperature which needles of some northern conifer seedlings could withstand was 49° C. for a two-hour period. In moist air they could tolerate 50° C. and in dry air 54° C. for a five-hour period. According to Lorenz (3) cortical parenchyma cells of catalpa, American elm, red pine,

northern white pine, and white spruce seedlings, were killed in 30 minutes when exposed to temperatures between 57° and 59° C. One minute was required to kill the cells at 65° to 69° C. From a review of the publications cited, as well as others, it is clear that different methods and durations of exposure to heat, interpretation of heat injury, and kind and age of material tested can greatly modify results. The commonly accepted statement that plant protoplasm is killed at 60° C. has little meaning unless properly qualified.

EQUIPMENT

Equipment used for testing the heat tolerance of southern pine needles consisted of a vacuum-jacketed calorimeter and a perforated cover (fig. 1). The cover was made of 5 layers of aluminum foil separated by layers of desk-pad blotter stock all fastened together with ordinary desk staples. A tightly fitting rim of heavy cardboard served to hold the top in place. Holes approximately 1/8 inch in diameter were spaced in a circle at intervals of about 7/8 inches. A central hole was made to hold the thermometer which was kept at the desired depth of immersion by tightly wound circles of a rubber band about it. All perforations were coated with clear waterproof cement.

Figure 1.--Calorimeter used to determine lethal temperatures for southern pine needles.

It was possible to control the temperature of water in the calorimeter far more closely than was expected. In pre-tests, by directing the beams of several 100-watt infra-red lamps at the lower one-third of the calorimeter, the temperature could be maintained at a constant level or even increased if desired. For example, in one test with three lamps at about 6 inches from the calorimeter, the temperature increase was 1.3° C. in one hour. In another test by changing the number of lamps and their distance from the calorimeter, temperature during a 2-hour period was raised from 59.5° to 60.9° and reduced to 59.6° C. by the end of the test. In actual use, the beginning and end temperatures rarely varied as much as 0.2° C. and in most tests temperature variations were not detectable by a thermometer read to 0.1° C. This simple method of temperature control obviated the need for more elaborate equipment such as stirrers and thermoregulators.

MATERIALS

One-year-old needles of pitch, slash, loblolly, and longleaf pine were used in determining killing temperatures. Pitch pine fascicles were collected in Asheville, N. C., and those of other species in the vicinity of Charleston, S.C.,

and Brunswick, Ga., in March and April of 1951. They were tested within several days after collection. No particular effort was made to be selective in collecting the needles. For the most part they were taken from the ends of branches within easy reach on trees ranging in height from 6 to 35 feet.

Shortly after being plucked from the trees, needles were placed on end with the sheath down in glass jars containing an inch or two of water. In the laboratory they were similarly kept in water except for brief periods of examination. All had the same initial temperature before immersion. At no time was there any indication that storing needles in this manner had a harmful effect, because control needles continued to transpire and remained in their original green condition until discarded. Needles have been kept in this way for as long as 5 weeks without apparent loss of turgor or color.

Only sound, entire fascicles were used in the laboratory tests. Here again, no particular pains were taken to sort out material on the basis of length, plumpness, or other physical characteristics. Differences within a species, however, are not believed to have been great.

METHODS

After water in the calorimeter had been brought to the desired temperature, fascicles which had previously been inserted in holes in the perforated top were quickly plunged into the water bath. Fascicles were immersed for about half their length and were kept at the desired position by means of small numbered tabs made of ordinary drafting tape which encircled the fascicles. Time of immersion was measured with a stopwatch. Fascicles were removed in order from the water bath as each in turn reached the predetermined time of exposure. Thus, both time and temperature of immersion were easily and accurately controlled.

Prior to the main experiment, a series of pitch pine fascicles were immersed at 60° C. for periods ranging from 0.25 to 2.0 minutes, the intervals being 0.25 minutes. Corresponding tests were made at 58°, 56°, and 54° C. but at other time intervals. Approximate values having thus been determined, after some days of observation, a second experiment was made to bracket the lethal temperatures more closely by lessening the time intervals of immersion. Subsequent tests with the other species followed the same pattern but over a greater temperature range--from 64° to 52° C. at two-degree intervals.

In the reported investigation a pronounced yellowing of the needles was considered a sure sign of injury. The procedure followed was to place a series of fascicles that had been exposed to the same temperature, but for different lengths of time, on a black surface for color comparison. Ordinarily, affected needles could be rather easily distinguished. At times, however, it was difficult to determine the exact breaking-point; as for example whether at 60° C. the critical time should be noted as 0.75 or 1.0 minute. Occasionally there were aberrant fascicles. One immersed for a minute might appear less injured than one immersed for three-quarters of a minute. Here an element of judgment entered into a determination of the death point and for that reason no precise time-temperature figure is claimed for every point. In addition to comparing one fascicle with another in the same series, and with untreated controls, a check of waning natural color was made between the treated and untreated parts of a fascicle. This permitted a 3-way comparison of affected and unaffected needle tissue.

Injury to fascicles that had been subjected to lethal temperatures, within the range used here, was not immediately discernible. At the higher temperatures and longer exposures, symptoms sometimes appeared within a few hours. Conversely, a week or more might elapse before a sure determination could be made for the shorter times and lower temperatures.

RESULTS

Results of the experiment are graphed in figure 2. The most significant fact shown by the graph is that pine needles were killed almost instantaneously at 64°, whereas at 52° they withstood 9 to 11 minutes of heat. Except for slash pine, each point on the graph is an average of two independent tests. It will be seen that at the higher temperatures, death points for the several species were in very close agreement but at the lower temperatures there was considerable divergence. The solid line in the graph represents an arithmetic average of the death points of the several species as best they could be judged.

From the data it appears that pitch pine may be somewhat the most tolerant species to heat, and slash the most susceptible. Whether there are real differences between species cannot be determined from the information at hand. If slight differences do exist, these are probably too small to be of any practical significance.

There are undoubtedly a number of factors beside time and temperature which can influence results of tests such as were made by the writer. Variability in test material such as needle mass, position of fascicles in the tree crown, their relative exposure to the sun, their age and physiological activity, all conceivably can have an effect.

Pine needles can probably suffer varying degrees of injury from exposure to high temperatures. Whether a large or small number of cells must stop functioning permanently before death ensues is not known. As Lorenz (3) points out: "True indices of heat injury, which make it possible to determine accurately the extent to which life functions of plants have been impaired, are noticeably wanting." There was no evidence from the investigations reported here that fascicles can be partly killed and then recover. More refined techniques will have to be used before this point can be determined.

Pine fascicles subjected to the same high temperatures in a fire as in a water bath may not react in the same way. Shirley (4) states that for comparable material the killing temperature was higher in air than in water and higher in dry air than in moist air. He also found that seedling needles could tolerate several more degrees of heat when exposed in dry air than in moist air. The difference was attributed to the cooling effect of transpiration.

The writer has no evidence that a free-burning forest fire either increases or decreases the relative moistness of the air surrounding a tree crown. Forest fuels during combustion release quantities of water vapor but the amounts undoubtedly depend upon the type of fire, fuel, and stand. Perhaps in most fires the water vapor is quickly dissipated or otherwise has no moderating effect on lethal temperatures. Whatever these phenomena are, it may not be unreasonable to assume that thermal death points in a fire should not differ greatly from those in a water bath.

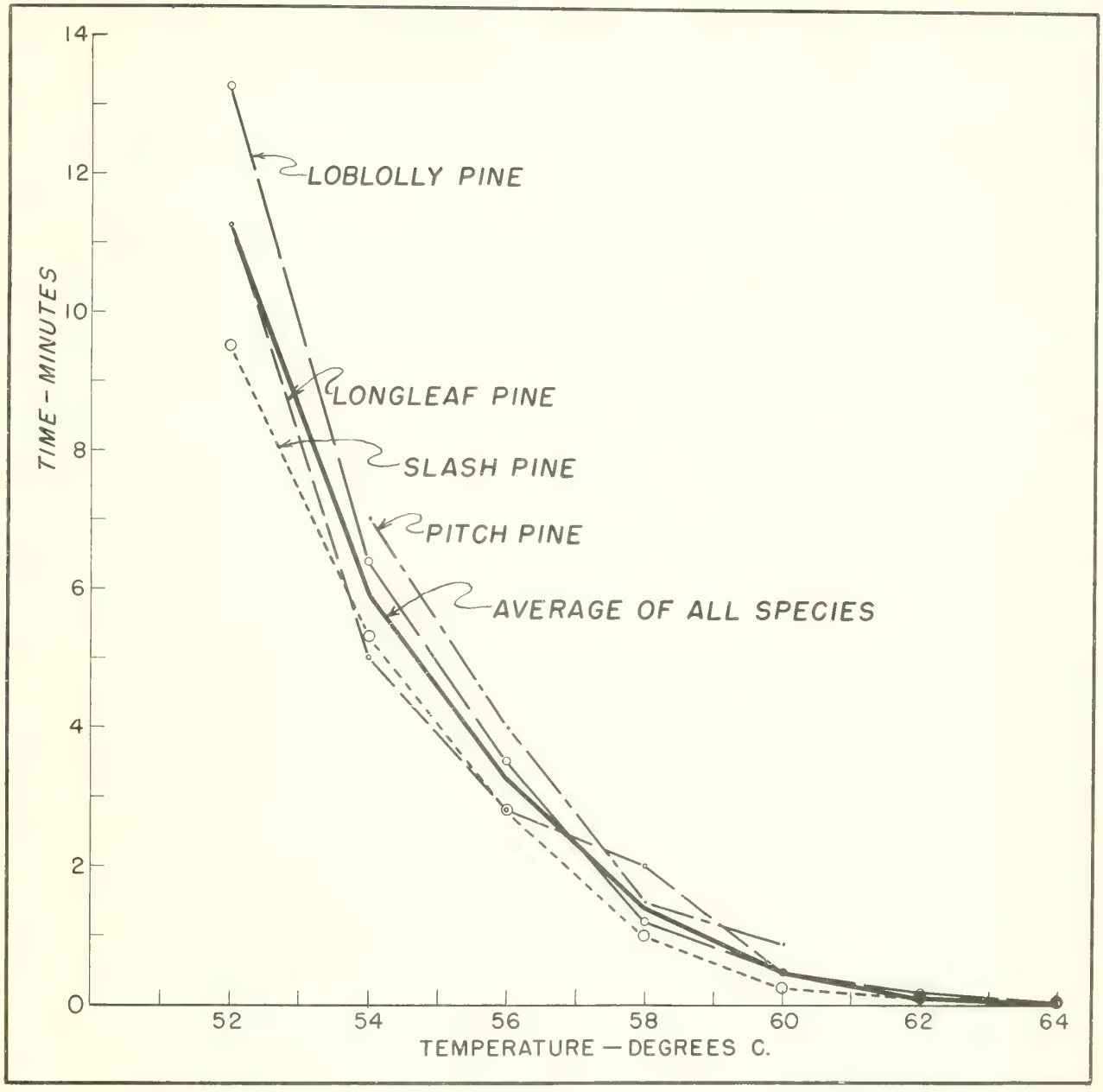

Figure 2.--Killing temperatures for southern pine needles when immersed in a water bath.

SUMMARY

(1) Fascicles of slash, loblolly, and longleaf pine were immersed in a water bath at temperatures ranging from 52° to 64° C. (respectively 125.6° and 147.2° F.), at two-degree intervals. Time of immersion ranged from 1-1/2 seconds to 14 or more minutes.

(2) Average lethal temperatures for the three species, supplemented by data from pitch pine, were as follows: at 64°, 3 seconds; at 62°, 5 seconds; at 60°, 31 seconds; at 58°, 1.4 minutes; at 56°, 3.25 minutes; at 54°, 5.9 minutes; and at 52° C., 11.3 minutes.

(3) Temperature of the water bath could be closely regulated by directing beams of infra-red lamps at the base of the calorimeter.

(4) Tests were not sufficiently replicated to determine whether species have significantly different thermal death points. If so, they are believed to be small.

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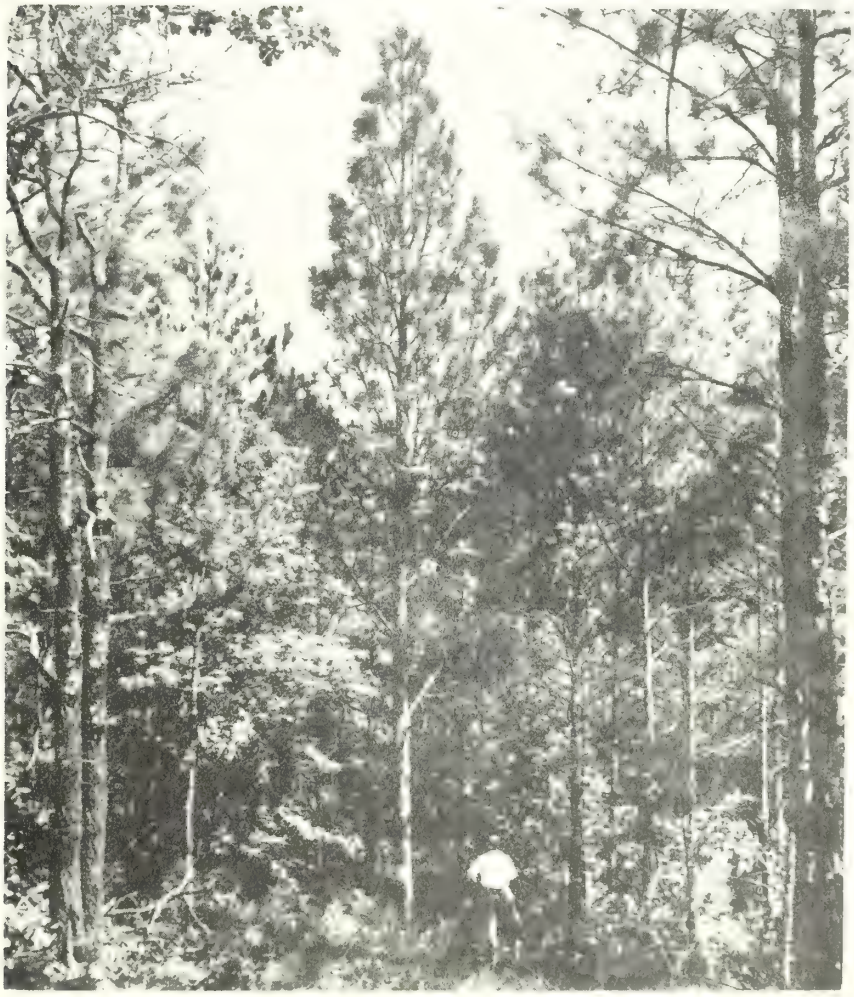
STATION PAPER NO. 15

MARCH 1952

HEREDITARY VARIATION AS THE BASIS FOR SELECTING SUPERIOR FOREST TREES

BY

KEITH W. DORMAN



FOREST SERVICE SERVICE

U. S. Department of Agriculture

Southeastern Forest Experiment Station

Asheville, North Carolina

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All photographs with the exception of figures 7 and 8 were made at the Ida Cason Callaway Foundation project in forest tree improvement, Hamilton, Georgia, by Daniel O. Todd, U. S. Forest Service, Atlanta, Georgia.

Previous publications and reports in cooperation with the Committee on Southern Forest Tree Improvement are:

1. Report of the first southern conference on forest tree improvement. Atlanta, Ga., January 9-10, 1951. Mimeographed. U. S. Forest Service, Atlanta, Ga.

2. Proposal for a cooperative study of geographic sources of southern pine seed. Subcommittee on Geographic Source of Seed, Philip C. Wakeley, Chairman. Mimeographed. Southern Forest Experiment Station, New Orleans, La. October 25, 1951.

3. Standardized working plan for local tests of seed source. Subcommittee on Geographic Source of Seed, Philip C. Wakeley, Chairman. Mimeographed. Southern Forest Experiment Station, New Orleans, La. October 24, 1951.

4. Hereditary variation as the basis for selecting superior forest trees. Subcommittee on Tree Selection and Breeding, Keith W. Dorman, Chairman. Southeastern Forest Experiment Station, Station Paper No. 15. March, 1952.

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HEREDITARY VARIATION AS THE BASIS FOR SELECTING SUPERIOR FOREST TREES

by
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INTRODUCTION

The Southern states are now producing 50 percent of the Nation's annual production of pulpwood, 40 percent of its lumber, a larger percentage of the poles, railroad ties and other products, and all of the turpentine and rosin. The South contains 40 percent of the commercial forest land, although this region is only 27 percent of the gross area in the United States. Until recently there has been little attempt in general silvicultural or forest management work to improve the genetic quality of the forest crop. We are planting more than 200 million trees each year in the South--enough to cover more than 200 thousand acres--yet little seed is collected from selected trees or strains of high vigor, quality, and resistance to pests. Instead of collecting seed where it is of high quality, we tend to collect it where it is abundant and cheap. We have recognized wide variability in tree quality in natural stands, but we have used the knowledge to increase economic returns by harvesting the better trees instead of using it to reserve good trees to regenerate new stands. These practices are dysgenic: they lead to degeneration of the crop, and no farmer, orchardist, or animal raiser would use them.

Some of our unsound practices are matters of expediency, but they should not become habitual. We can maintain the genetic quality of the present forest and improve those of the future by adopting a three-point program of.

(1) Establishing new stands by planting or natural methods with seed from the best trees in the best stands.

(2) Making tests, with seed or grafted material, of the best trees, stands, and races to isolate the best types, so that superior seed can be produced in the future.

(3) Starting a program of tree breeding to create new types.

The first step in this program insures use of what we think to be the best stock at present. The second will provide us with good indications in the near future as to which of the selections are the best stock and some indication of how superior they are. The third will provide, at some time in the future, new types of proven superiority.

The first two steps in the above program assume that heritable variation occurs between trees, and that we can recognize it. Do we know this?

The answer is yes, and the proof lies in the results of many test plantings described in the following sections.

In his discussion of the basis of individual variation, Stebbins (1950) states: "The variation seen between the individuals of any population is based on three factors: environmental modification, genetic recombination, and mutation. Of these, environmental modification is the least important in evolution, although sometimes very conspicuous. As mentioned . . . . the first step in any analysis of natural variation is the performing of transplant experiments by which the effects of environmental differences are largely neutralized. Such experiments have shown that each genotype has its own genetically determined degree of modification or plasticity. The adult individual we see, therefore, is a phenotype which is always the product of the effect of a given environment on an individual with a particular hereditary background, or genotype. That this axiom of genetics disposes at once of many futile arguments as to the relative importance of heredity and environment, or 'nature and nurture,' has been pointed out by many geneticists. . . ."

The first step in studying variation in forest trees should be to review what is known about the influence of each of the three factors listed above. This should tell us how to look for variation, how to recognize it, and how to evaluate it by test plantings. Because this background is necessary, the following sections give in some detail the results of many studies in this and foreign countries. They also cover many species because what is common in one may be common in others. This summary gives us a basis upon which to build plans for studies of natural variation in local species, and the remainder of the discussion is concerned with this phase of the job. It gives the characters that are important in vigor, quality, and resistance to pests, and discusses what variation has been observed in studies up to this time. Also, there is a discussion of the qualities important in utilization for various products. We must be alert and recognize valuable material, because we don't know what will be found. If the limits of variation were known and we could set up final standards for superior trees, there would be no need for additional work.

Some of the variation between phenotypes of southern pines is illustrated by the photographs which follow in figures 1 through 16.

Figure 1.--A slash pine tree (Pinus caribaea Mor.) that is 55 percent larger in diameter than the average tree in the same section of the plantation. Its basal area is 2.4 times that of the average tree. The tree is 15 years old, 10.7 inches in diameter, 59 feet tall, and has good form.

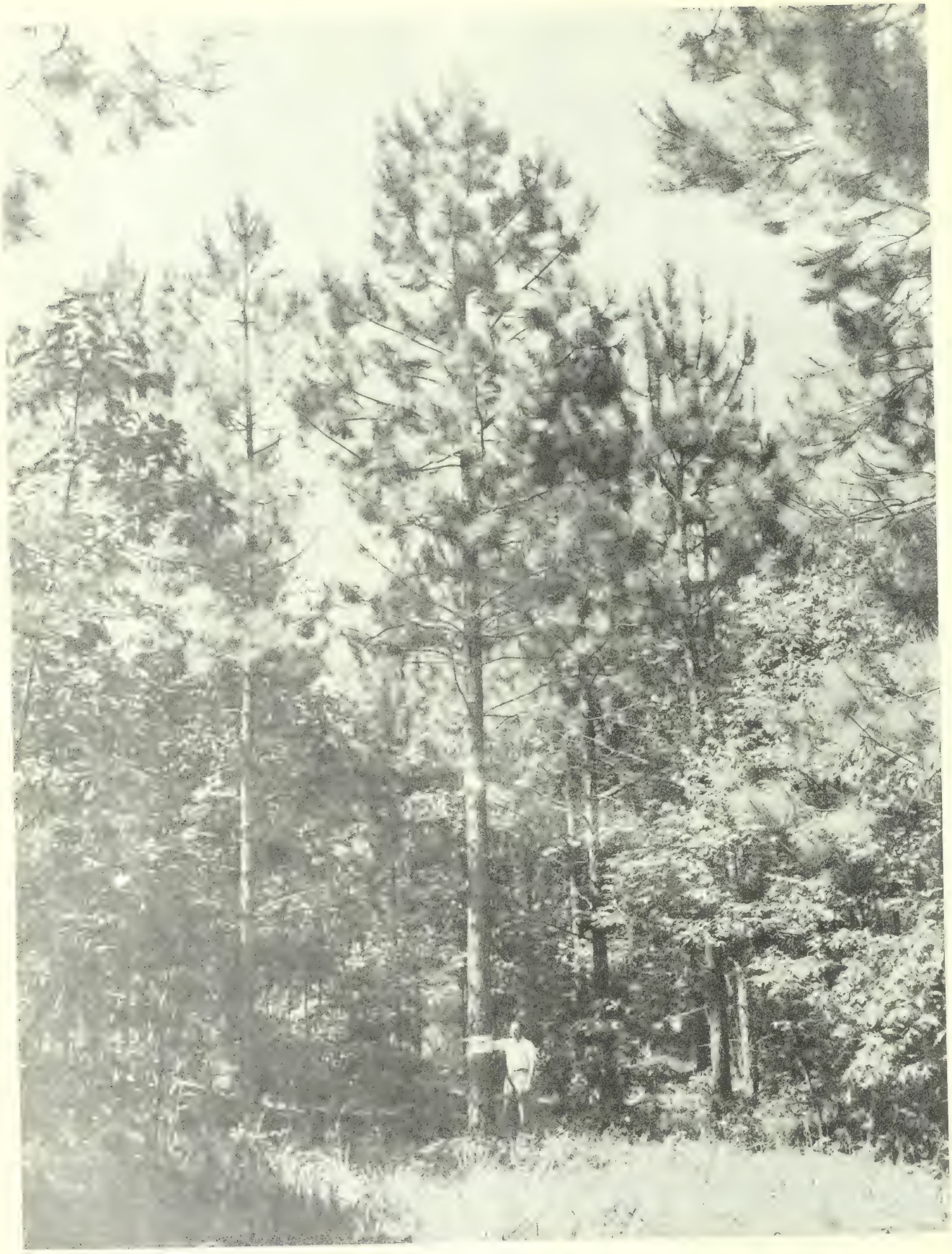

Figure 2.--Fifteen-year-old slash pine with high vigor and good form. Although growing very rapidly, it has pruned itself well. The branches are not overly large and the trunk has little taper. The tree is 12.7 inches in diameter and 54 feet tall. This is an extremely good type, and it is suitable as a mother tree.

Figure 3.--Fifteen-year-old slash pine with high vigor but very poor form. It has been growing nearly an inch a year in diameter, but it is poorly pruned, the branches are large, and the stem has excessive taper. The tree is 13.6 inches in diameter, 48 feet tall, and it is one of the largest trees in the plantation. It is growing within a few feet of the good phenotype shown in figure 2.

Figure 4.--Longleaf pine (Pinus palustris Mill.) of good stem and crown form and high vigor. The tree is 30 years old, 13.5 inches in diameter, and 58 feet tall.

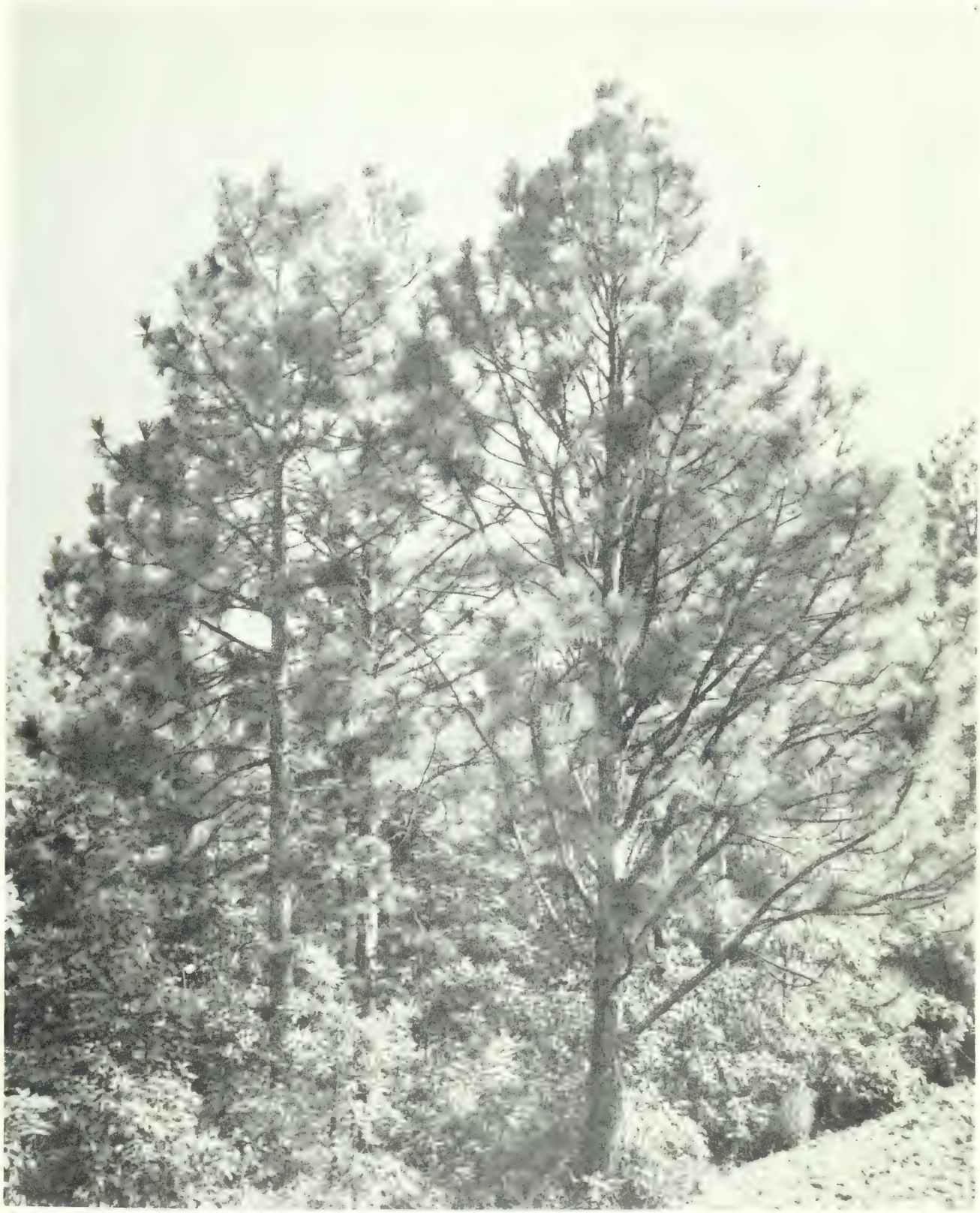

Figure 5.--Longleaf pine (on the right) with undesirable crown form. Poor natural pruning, branchiness, and excessive stem taper make this a poor mother tree. Trees of better form appear on the left.

Figure 6.--Longleaf pine with fastigiate form. This tree is 26 years old, 12.8 inches in diameter, and 65 feet in height. Although this is a very vigorous tree, and the crown is very slender, this type of branching habit may not be desirable, because natural pruning may be slow. However, some foresters prefer slender-crowned trees because they occupy a small amount of space.

Figure 7.--Longleaf and loblolly pine may cross in wild stands. The offspring are called Sonderegger pine, and they are usually poorly formed trees, although vigorous. This natural hybrid shows morphological characters intermediate with the parents.

Figure 8.--Shortleaf pine (Pinus echinata Mill.) of good form and high vigor. The tree is 25 years of age, 13.1 inches in diameter, and 62 feet tall. Although it is not growing under competition, the tree is fairly well pruned and branches are not objectionably large.

Figure 9.--Shortleaf pine of high vigor but poor form. The tree is 25 years old, 15.6 inches in diameter, and 62 feet tall. Although the crown is slender and the branches small, there is a strong tendency to crook, and the tree is poorly pruned.

Figure 10.--Shortleaf pine of good form and high vigor. It is 15 years old, 9 inches in diameter, and 26 feet tall. The small branches are nearly at a right angle to the stem, and with competition this type of tree would be well pruned.

Figure 11.--Shortleaf pine (center) of high vigor but poor crown conformation. The branches are long and large in diameter. The tree is 16 years old, 11 inches in diameter, and 34 feet tall.

Figure 12.--Loblolly pine (Pinus taeda L.) on the left, 26 years of age, 18.3 inches in diameter, and 69 feet tall. This fast-growing tree is the same age as the 10.4-inch loblolly pine on the right.

Figure 13.--Loblolly pines with wide variation in crown width. The crown spread of the tree on the left is 20 feet, that on the right 40 feet. Slender-crowned trees are preferred because the branches form small knots and are easily pruned.

Figure 14.--Loblolly pine 22 years of age, planted at Bogalusa, La., shows the effect of geographic source of seed on height growth. Source of seed in rows of trees, from left to right, Louisiana (local), Texas, Georgia, and Arkansas. Photo from Wakeley (1951a).

Figure 15.--Total merchantable pulpwood produced on 1/8 acre (a piece of four loblolly pine stocks) 22 years after planting at Bogalusa, La. Seed source, from left to right, Louisiana (local), Texas, Georgia, and Arkansas. Photo from Wakeley (1951a).

Figure 16.--Open-grown loblolly pine that exhibits poor natural pruning. The strongly ascending branches tend to persist for a long time. Horizontal branching is preferable.

THE HEREDITARY-VERSUS ENVIRONMENT CONTROVERSY

It should be understood that all plant characters are heritable--the important thing is the rigidity of genetic control. If a character is loosely controlled (plastic in nature), then environmental changes can so alter the character that the genetic control becomes of little importance. Conversely, some characters are now so rigidly controlled genetically that the environment is of little importance. Some people have assumed there was no heritable variation in tree species, and they planted seed regardless of geographic source of seed until they found some sources were undesirable; they cut the best trees until they discovered most of the trees in succeeding stands were of generally lower quality. They collected seed indiscriminately until they discovered some poorly formed mother trees gave poorly formed progeny. Foresters who have encountered such experiences believe there is heritable variation within species of trees. The explanation that all observable differences are merely the effect of "environment" is no longer acceptable in the face of the growing volume of experimental evidence demonstrating heritable variation.

The breadth of heritable variation can perhaps best be stated by a quotation from Mather's (1949) book, "Biometrical Genetics." He states, "A great variety of characters is now known to show heritable variation. It includes gene and chromosome behavior, cell shape, gross morphology, physiological and biochemical properties, psycholcgical characteristics, mating behavior, resistance to disease and toxic agents, ability to infect a host, ability to act as a vector in virus transmission, and antigen production. Indeed, few geneticists would question the proposition that no character of an organism would fail to show heritable variation were it subjected to adequate examination. Furthermore, the magnitude of the heritable differences shown in a character may range from the smallest that is detectable to the largest that is possible." The more one studies the complex nature of some of our important tree species the more he sees the spectrum of variations, many of which are doubtless inheritable. Stebbins (1950) expresses this very well when he states, "A thorough study of Nature's variation pattern reveals that fickle Dame Nature has very different ends in view from that of making neat hierarchies of species and genera which naturalists can file away tidily in cabinets with the least possible trouble."

The species concept in plant taxonomy does not imply genetic uniformity. Taxonomists or plant systematists who use the broad concept of the species are called "lumpers," and those using a narrow concept are "splitters." They disagree on the point of how "uniform" a species must be.

The geneticist, the ecologist, and the systematist has each developed terminology to describe categories below the rank of species. Some of these terms will be listed in passing because a full explanation of their derivation is beyond the scope of this paper. Stebbins (1950) gives a number of them in his discussion of variation patterns. He describes varieties and subspecies as units within species and the form as a unit within either subspecies or species as they are all used by plant systematists. Also, the biotype, pure

line, clone population, and ecospecies or ecotype are explained as they are used by geneticists.

The biotype consists of all the individuals having the same genotype. Since even a small amount of cross-fertilization will produce heterozygosity and differences between genotypes for at least a few of the hundreds of genes present in any organism, the biotype in cross-fertilized organisms usually consists of a single individual. But in self-fertilizing plants the individuals may become completely homozygous and produce by selfing a progeny of individuals all with the same genotype, and therefore belonging to the same biotype. The offspring of a single homozygous individual is called a pure line, which therefore represents the appearance of the same biotype in successive generations. When asexual reproduction occurs, either through vegetative means or through apomixis, several individuals of the same biotype may be produced even if the parent is heterozygous. All asexually produced offspring of an original individual are collectively termed a clone. A population is a group of individuals among which interbreeding and gene exchange can occur. Usually plants interbreed with others of the same species that are adjacent to them in the population. Because of the distance, they do not mate with those in other parts of their natural range. Moreover, a difference in blooming time prevents them from mating with those in the same locality but at different elevations. Ecospecies or ecotypes are distinct races resulting from the selective action of a particular environment.

The lack of uniformity has led to many problems in describing species, such as Douglas-fir, ponderosa pine, European larch, and many others, as we will learn from the following discussion. Variation within a species creates opportunities for locating better types, and raises problems in avoiding undesirable types. It may be just as great an error in judgment to use the wrong race, variety, or variant of a species as it is to use the wrong species.

Between the growth habit exhibited by the prostrate juniper and the West Coast redwood--between the slender, fastigiate form of Lombardy poplar and the "weeping" willow--lie many intermediate types, and no one denies that the extreme type of form exhibited by these plants are heritable; no one should deny that smaller differences in crown or stem form can be inherited. We don't expect to change the inherent form of "weeping" and fastigiate types, or the dwarf and giant types, by growing them in different environments.

The tree that grows in the woods (the phenotype) is a product of the environment and genetic constitution (the genotype). While we can detect major genotypic effects which separate the species--the maples from the oaks, the pines from the cedars--there are other smaller differences in genotype, within a population, which can be accurately determined only by studying the tree's progeny. Such studies are made with offspring obtained by controlled pollination, showing traits passed on through inheritance in sexual reproduction. Progeny tests may be necessary in precise experimentation, or before making an investment to reproduce the stock as a superior variety. They are not a prerequisite for most silvicultural selection where a great many selections are made.

In contrast to the differences between individuals within a population

there are differences between populations. These differences between groups of trees of the same species have been recognized by the plant systematists, ecologists, and geneticists, as discussed previously by Stebbins. They may be common in species with a wide geographic range where differences in minimum and maximum temperatures, length of growing season, and many other factors act through natural selection. These factors of natural selection acting upon generation after generation gradually eliminate those trees less suited to local conditions. Natural selection can be effective only if there are different genotypes within the population. These differences between individual trees may be caused by mutations or recombination of genes, and they will be discussed in more detail in following sections.

The argument of environment versus heredity should not be permitted to delay any longer the use of better parent stock of forest trees in the selection of outstanding trees to form the final crop or for a source of seed. Our obligation is to find out whether superior types exist, and if so, to use them. Foresters have yet to catch up with workers in other fields of agriculture in recognizing the opportunities furnished by variation within species.

THE BASIS FOR HERITABLE VARIATION

The improvement to be made by selecting superior single plants or races depends upon the amount of heritable variation. It will help in establishing a frame of reference for selection work if we review the three broad factors of variation that were listed in the introduction and the effects of each; also, if we assemble the results of studies showing the extent of this variation. With this groundwork we will be in a position to develop methods and preliminary standards of selection applicable to the South.

Studies of variation in forest trees are reviewed in three sections under the headings of variation through recombination, variation caused by mutations, and variation between populations. These divisions of subject material are not strictly comparable because only recombination and mutation actually cause variation, which then may be acted upon by natural selection to develop varieties. Recombination and mutations cause variation within populations, and natural selection causes variation between populations. Standard works in genetics should be referred to for a full discussion of these subjects, because space limitation prohibits adequate coverage here.

Variation Through Recombination

Heritable variation that causes differences between plants of the same species may be caused by various combinations of genes that control growth and form. We know from the tests made with cuttings, seed from controlled breeding, and seed collected from single trees exhibiting certain traits, that a good many of the visible traits may be truly hereditary. Because of its value and application to forestry practices at the present moment, the following discussion covers in some detail the results of tests where seed is taken from selected trees and the offspring compared with the mother tree or with those of other trees. This is the result of mother tree, or one-parent selection, and in general shows that traits both good and bad may be transmitted to some of the next generation regardless of the male parent.

One-parent progeny tests with softwoods.--In Australia, according to the Queensland Forest Service (1950), seed of loblolly and slash pine have been collected usually from selected trees of the best form and vigor. In order to know whether or not this was a desirable practice, controlled test plantations were made in 1942 and 1944 with seed from crop trees (the 160 chosen for pruning, out of an original planting of 680 per acre), from a more highly selected group of "plus" trees and with seed resulting from inbreeding a few of the selected plus trees. In 1948 the trees were measured and rated on the basis of form and growth. When the average results for the three groups were expressed as the number of stems per acre of form equal to or better than the best 160 per acre of routine source, they found the open-pollinated seed from the plus trees gave 350 stems and the inbred seed source 570. The progeny of 9 of the 11 plus slash pine trees was significantly superior to those from the routine collected seed from the 160 pruned trees. A similar test with loblolly pine seedlings showed 310 trees per acre from the plus seed equal to or better than the best 160 from the routine

collected seed. The progeny of 12 of the 13 plus trees was superior to that of the routine seed source. The selection of both slash and loblolly pine was made in plantations where environmental conditions were fairly uniform. In all cases in the above experiment there was a range of types from good to poor in the progeny of each plus tree. By selecting open-pollinated seed from the plus trees, the Australians obtained more than twice as many top-quality trees. By inbreeding the best slash pine plus trees, they obtained 3.5 times as many top-quality trees and 15 percent were better than any from open-pollinated crop trees. These results may be conservative if a comparison is desired between plus trees and average trees, because these plus trees were compared with the offspring of crop trees which were the best 25 percent of the stand, instead of with average trees in the stand. The crop trees would be those regenerating the next stand unless they were removed to make a commercial thinning or as a result of naval stores chipping, both of which are sometimes done in the southern United States.

Minckler (1942) reported 5-year results of a one-parent progeny test with loblolly pine trees. The planting was then destroyed by a hydroelectric project. Although no criterion was discovered for selecting seed trees, the data did show highly significant statistical differences in both growth and survival of progenies from different mother trees. The mean growth in four randomized plots of the best progeny was 8.3 feet and the poorest 5.4 feet. The mean survival of the best progeny (from the standpoint of survival) was 96 percent and the poorest 5 percent. The 10 best progenies from the standpoint of growth grew 36 percent more in 4 years than the 10 poorest, and the 10 best from the standpoint of survival were 48 percent better than the 10 poorest.

Sherry (1947) has shown that both desirable and undesirable characteristics of Monterey pine (Pinus radiata) mother trees grown in South Africa may be passed on to their offspring. Seed was collected from 14 parent trees which exhibited marked character in regard to vigor, branch thickness, length of internodes, stem form, and crown form. At 7 years of age, the progenies, about forty trees from each parent tree, were measured and scored for morphological characters. The results are expressed as the percentage of each progeny which reproduce the characters of the maternal parent. Data from two of the progeny groups will illustrate the type of results obtained from the plantation. One mother was selected for high vigor, small branches, relatively short internodes, straight stem, and narrow crown. The progeny showed 89 percent with small branches, 91 percent with short internodes, 96 percent with straight stems, and 47 percent with narrow crowns. Another rapid-growing mother tree that had small branches, long internodes, crooked stem, and wide crown gave progeny 73 percent of which had small branches, 37 percent long internodes, 74 percent crooked stems, and 55 percent wide crowns.

The range in number of offspring showing the characteristics in stem form and crown shape of the mother parent is very interesting, although the number of examples cited is rather small. They are given by Sherry as examples, not averages, of the range that occurred from the 14 mother trees. Generally, about 45 percent at the lower limit (33 to 57 percent) to about 85 percent at the upper limit (72 to 96 percent) of the offspring showed the same traits as the mother tree. Sherry concludes that, "A surprisingly high percentage of trees in these progenies resembled the maternal parent in the characters which were scored, suggesting that these characters are genetically controlled . . . . There are indications from the data that characters such as slender branches

and short internodes may be genetically dominant and that defects in the crown and leading shoot are heritable. The results, in general, suggest that mother tree selection in the collection of seed from P. radiata may effect considerable improvement in the form of resultant crops."

A number of studies in Europe show that in Scots pine the mother tree influences form and vigor of the offspring. Lubyako (1941) found significant differences in the average height and diameter of progeny of different pine trees at the age of 13 years, though there was great variation within each progeny, even the best containing over 20 percent of individual trees having a height below the average for the worst progeny group. In another investigation, 11-year-old progenies of first-quality stands averaged 1.8 times the height and over twice the diameter of those of third-quality stands. Behrndt (1935) reports results obtained by individual selection in three plantations, consisting of the progenies from single trees and seedlings obtained from certified seed. For the 7-year observation period all three plantations demonstrated differences in the height attained by the various progenies of the same age from single trees. These differences are regarded as being partly due to direct genetic causes and partly to differences in susceptibility to Lophoderium pinastri. Progeny on one tree in one of the three plantations exhibited remarkable resistance to this fungus throughout, as well as a particularly high growth rate.

Syrach Larsen (1937) has reviewed early European work with open-pollinated seed in forest tree-improvement programs, and cites several workers who claim that the characters of the mother tree are dominant in the offspring of the individual tree.

Arnborg (1946) describes a form of Scots pine called "broom" pine. It is characterized by fastigiate multiple stems formed in youth, and generally fused later into a composite stem from one to several meters long in old trees. No true main stem is formed. Cone setting is usually poor and cones small, but no distinct differences from type exist in the general morphology of leaves or cones. The form is practically confined to Uppsala and the adjacent counties in Sweden, but possibly occurs in several Norwegian localities. Seed from parents in a number of localities was sown in 1942. In the 4-year-old progeny only 23 percent had straight, single stems with short branches, 65 percent had single stems but long branches, and 12 percent had two or more stems. The difference in seedlings begins to show in the first to second years.

Differences were found by von Wettstein (1949) between the progeny from open-pollinated seed of selected Scots pine trees and that from mixed seed of all trees in the same stand when planted in alternate rows. The differences were consistent for yearly plantings over a 5-year period, and he suggests this method for separating elite trees from standard or average trees.

Johnson (1948) describes two cases of albinism in seedlings of Pinus nigra var. austriaca. In one case, seed was collected from an isolated self-pollinated individual tree. The other seed came from a group where some cross-pollination was likely to have occurred.

An unusual type of spruce, called "worm" spruce in Sweden, is described by Geete (1944). Treschow (1944) reports on progeny of spruce of this type. Of 400 plants raised from seed collected in 1922 from a single tree--the only one of its kind in the stand--most offspring appeared at 4 to 5 years of age to be ordinary Norway spruce. The remainder (16 plants) were planted out, and are still of a pronounced "snaky" type. Five or six of them are quite typical, with several annual shoots having no lateral shoots whatever, and have therefore stagnated in growth. The rest, though of the "snake" type, have formed almost normal leaders of late years and have grown fairly well; the largest is now 10.7 meters high and 21 centimeters in d.b.h.

In Wisconsin, Riker, Kouba, and Brener (1949) found that seedlings from wind-pollination of selected rust-resistant white pine trees had little more resistance to blister rust than commercial seedlings. Grafted trees, from the 163 parent trees that had been selected in natural stands because of their apparent resistance, were variable in resistance to the disease. About one-fourth of them had high resistance. Resistance to blister rust occurred in one or more of these ways: (1) infection negative or reduced in amount, (2) needle lesions reduced to small spots or flecks, (3) stem lesions corked out, (4) lateral stem lesions failed to reach the main stem before the twig died, and (5) cankers failed to form aecia.

One-parent progeny tests with hardwoods.--The earliest work in individual tree selection in hardwoods was in Europe with beech, about which Syrach Larsen (1937) states, "Cieslar and Opperman's works, published in the beginning of this century, were pioneer works in the recognition of the hereditary differences in shape in individuals of apparently the same geographical type. Both took a special interest in the so-called freak forms. Opperman's work was of the greatest importance to Danish conditions. His comparison between offspring of marked weeping beeches and other normal trees, and with offspring of isolated, particularly beautiful, individual trees, or whole growths of particularly fine specimens, give a strong impression of the necessity of seeking the best possible seed trees also within the individual districts. He created the word 'freak' as a forestal term denoting a tree with poor hereditary properties with respect to shape. At the Egelund nursery he demonstrated his experiments in such a manner that it was impossible to leave the nursery without feeling an urgent desire to apply these results. Opperman roused Danish foresters from indifference with regard to the origin of seed, and throughout his life he urged us to gather seed from the best possible trees only."

Selection of trees superior in latex production has been an important part in the development of improved rubber-producing trees of Hevea. Through a program of selection and controlled breeding with the use of bud-grafted superior types, the best stock is expected to produce about 2,000 kg. per hectare as compared with a yield of 460 to 640 kg. per hectare of the unselected plantations in 1926. Seed from superior trees does not always give high-quality progeny, and some average trees may have progeny that are superior to the parent tree. Practically no effort has been made to improve growth rate by selection, as hybridization seems more feasible. Maas (1948) states, "Thus far seed selection has already resulted in trebling the productive capacity, and further increases can be looked to in the future, now

that sufficient information is available to extend the range of the recommendations. The difference in the productivity capacity of seedling plots as compared with bud-grafted plots has been smaller than had originally been expected, and this difference can still further be reduced by closer planting and selective thinning, methods better suited to seedling areas than they are to a monoclone planting. When a comparison is drawn between buddings and seedlings growing under conditions similar as regards planting distance and thinning out, the figures show that the rate of production does not exceed 15 percent in favor of the buddings, and in many cases it has proved to be a good deal less. . . . The planting of seedlings should be included in planting programs on a scale larger than hitherto, but the selection of the planting material should be referred to expert advice."

Open-pollinated seed of mimosa trees resistant to mimosa wilt produced trees about half of which were likewise resistant to the disease. Toole and Hepting (1949) found only a very few resistant seedlings when seed was collected without regard to resistance in the parent. Rooted cuttings from resistant trees show high resistance to the disease, and about half the seedlings were resistant when open-pollinated seed was collected from the trees developing from these cuttings.

Dilatush (1950) states that hollies grown from seed vary in the way leaves are retained throughout the year, leaf color, fruit color, permanence of fruit color, tree form, growth rate, and in the way the fruit is distributed among the leaves. Zimmerman and Hitchcock (1933) class seedling variation in holly under the following headings: (1) shape of plant, (2) fruitfulness, (3) color of fruit, (4) shape of fruit, (5) color of foliage (yellow to dark green), (6) shape or form of leaves (entire to very spiny or smooth to very twisted), (7) shedding of leaves, (8) winter hardiness, and (9) color of new leaves and stems.

Osborn (1931) was the first to make progeny tests with black wattle (Acacia mollissima Willd.). Between 1927 and 1930 he set out about 300 progenies from natural seed of selected trees in alternate rows with seedlings from commercial sources. He found that a remarkable degree of uniformity occurred within many of the progenies while others did not breed true to the same extent; that superior characters--mainly vigor, form, foliage, disease resistance--appeared consistently within a number of progenies; and that recessive lethal and developmental modifying characters appeared mainly in the seedling stage in some progenies. In some cases the standard deviation of basal area for the offspring of a selected tree was only about half that for a group of trees of commercial source. Osborn observed that isolated trees produced fertile seed and that recessive seedling characters occurred in natural progenies of plantation trees. This indicated that black wattle was not self-incompatible. He concluded that the studies of variation in vigor, bark yield, and tannin content provided sufficient evidence to recommend mass selection as a preliminary step in the improvement of the variety.

Black locust seed from fast-growing trees should be preferred over that of other trees, according to Cummings (1947). Seed was collected from 27 individual trees of different vigor classes, and after 6 years the seedlings averaged 9.1 feet in height for progeny of trees of good growth, compared with 7.0 and 7.7 feet for progeny of trees of fair and poor growth,

respectively.

Esson (1946) reports that fastigiate oak reproduced from seed. Of three acorns collected in 1931 from a specimen of Quercus robur var. fastigiata growing at Great Neck, Long Island, two produced ordinary English oaks with spreading branches, and the third a fastigiate tree that is now 34 feet tall.

Much variation of individual tree characters has been observed in cinchona plantations (Ferguson 1946). Clones vary in height growth, stem form, and branching. Quinine content of the bark is also genetically determined. Ebes (1951) discusses results of selective breeding with Cinchona ledgeriana. An improved stem form was found in the first generation.

The point that stands out from this review of tests made with open-pollinated seed of both superior and inferior trees is that a large number of traits important to foresters in establishing, managing, and harvesting forest stands are heritable. Some of the characters are dominant and they are passed on to many progeny, while others are passed to a few progeny. This applies to both pine and hardwoods. Traits such as high vigor, good form, and disease resistance are most important to the practicing forester, and the case for selecting outstanding trees with these traits is well supported. These individual trees could be used as source of open-pollinated seed for large-scale planting, for grafting and cutting material with which to establish seed orchards, and for parent trees in controlled breeding. There is strong evidence for the careful selection of the best trees to form the final crop and for seed trees where this system of regeneration is used. There is a great need for additional studies in natural variation in commercial species of forest trees. We need progeny tests of the offspring of selected trees to show the proportion of variation contributed by environmental and genetic factors.

Variation Caused by Mutations

Another source of variation that may cause differences between plants of the same species is mutation. Mutations are sudden variations that are later passed on through inheritance and that result from changes in a gene or genes. Mutations in forest trees have been identified in both softwoods and hardwoods. A tetraploid (four chromosomal sets) has been reported in spruce from Sweden by Andersson (1947). The progeny resulting from wind pollination of the polyploid spruce show varying height growth, growth habit, and stomatal size. The Institute of Forest Genetics in California has what is believed to be a mutant shortleaf pine. It is characterized by slow growth, thin crown, and very short needles. Guinier (1944) describes a group of three branchless firs growing close together. The trees were very small and about one-half centimeter in diameter and 75 to 80 centimeters in height, although the trees were 30 years or more old, as indicated by the appearance of scars left by the fall of bud-scales. It is believed they were apparently the result of a mutation characterized by abortion of the lateral buds. Stebbings (1948) found the coast redwood was a hexaploid with 2N = 66

chromosomes. The dawn redwood recently discovered in China has 2N = 22 chromosomes, as does the big tree of California. Liese (1935) presents evidence for the hereditary nature of witches-broom on pine. Pine cones gathered from witches-broom yielded a progeny half of which showed the typical anomalous form of growth, while the other half of the progeny was normal. A second experiment gave similar results, except for the presence of a group of intermediate types. The author attributes the formation to bud mutation, asserting that the most careful investigation has never yet revealed the presence of a causal pathogenic parasite in the growth.

Chromosome counts have been made for a large number of hardwood species, and also in many unusual cases where anomalies were suspected. It is apparent that irregularities occur in both basic chromosome number and amount of natural polyploidy. Table 1 gives the chromosome number for several genera and some of the polyploid species or varieties. It shows the basic number is not uniform in Cornus, Ilex, Robinia, and Salix. Also, some very important genera, such as Acer, Betula, and Fraxinus contain many polyploids. Chromosome number has not been determined in some species and varieties of southern forest trees and additional study of this important subject may uncover other examples of polyploidy.

In some genera of hardwoods polyploidy has formed the basis for separating species; in others the basis for separating varieties. Although the original specific and varietal classifications were made on the basis of external morphological differences, these classifications were later confirmed by cytological study. Some large genera like Quercus show no natural polyploidy. The genus Betula presents an interesting example of polyploid series. Darlington and Janaki Ammal (1945) list 19 species and 5 varieties in this genus. Twelve species have the diploid number of 28 chromosomes. There are seven polyploid species with 56, 70, or 84 chromosomes. Paper birch, Betula papyrifera, is a tetraploid species with 56 chromosomes, and varieties cordifolia and subcordata also have this number. However, variety kenaica has 70 and occidentalis has 84 chromosomes. Alnus, or alder, the other genus in the family, has 28 chromosomes and polyploid types with 42 or 56 chromosomes. It is easy to speculate how the present species in the Betucaceae may have developed from original forms with a haploid number of 7 chromosomes (diploid number 14). It should be pointed out that chromosome counts are often made on single trees, and more data is needed before we can be certain the published figures hold for a species or a variety.

A number of methods for inducing mutations have been in use recently, and have been particularly successful in aiding breeding programs with small fruit, vegetables, and ornamental flowers. The drug colchicine is effective in doubling or multiplying sets of chromosomes, while radiation by X rays may cause changes in arrangement. Trees with multiple sets of chromosomes may have special value for their increased vigor and size, as well as for the larger cell size. Duffield (1943) and Wright (1944) have suggested polyploidy may be responsible for the variation in wood quality of some of the hardwoods. Wright (1944) found the tetraploid and hexaploid white ash growing with normal types. Nilsson (1943) found that triploid aspens had cells 50 percent larger than those of diploid types, and yielded a higher percent of cellulose. Whether or not chromosome doubling, which results in increased cell volume, can be used to create types of hardwoods that grow rapidly and still produce

Table 1.--Some genera of hardwoods which show variation in basic number of chromosomes or whose species or varieties form polyploid series

Genera	Diploid species		Polyploid forms	
	Species with diploid chromosomes	Diploid chromosome number	Species with polyploid chromosomes	Chromosomes in polyploid series
	Number	Number	Number	Number
Acer (maple)	18	26	4	52, 78, 104
Aesculus (buckeye)	4	40	2	60, 80
Alnus (alder)	7	28	5	42, 56
Betula (birch)	11	28	9	56, 70, 84, 90
Carpinus (hornbeam)	7	16	1	32, 64
Carya (hickory)	5	32	4	64
Cornus (dogwood)	2	20		
Cornus (dogwood)	8	22		
Diospyros (persimmon)	5	30	2	60, 90
Fraxinus (ash)	5	46	1	92,138
Ilex (holly)	1	34		
Ilex (holly)	2	36		
Ilex (holly)	4	40		
Magnolia (magnolia)	4	38	6	76. 95,114
Populus (poplar)	12	38	5	57, 76
Robinia (locust)	6	20	2	30
Robinia (locust)	1	22		
Salix (willow)	22	38	20	76,114,152
Salix (willow)	2	44		
Tilia (basswood)	7	82	4	164
Ulmus (elm)	11	28	1	56

wood of light weight has not been proven. The possibility is indicated by Johnsson (1950), who found density of wood in alder was lower in a cross between a polyploid derived from colchicine treatment and a diploid type.

However, there is some indication that weight of wood increases with increases in sets of chromosomes where polyploid species occur in the same genera. No data are available for polyploid forms of the same species. Table 2 contains the average weight of dry wood, as given by Markwardt and Wilson (1935), for several species of magnolia, birch, and hickory that form polyploid series. There are many factors that affect weight of wood, and they may be more important than chromosome number. However, the effect of polyploidy on wood quality is a field of work that could profitably be studied.

Table 2.--Relationship between number of chromosomes in magnolia, birch, and hickory, and weight of wood

Species	Diploid chromosomes	Annual rings per inch in test samples	Weight of dry wood per cubic foot
	Number	Number	Pounds
Magnolia fraseri	38	15	31
Magnolia acuminata	76	14	33
Magnolia grandiflora	114	15	35
Betula lenta	28	27	46
Betula populifolia	28	-	35
Betula papyrifera	56	6	38
Betula lutea	84	16	43
Carya cordiformis	32	11	46
Carya laciniosa	32	19	48
Carya ovata	32	19	50
Carya alba	64	18	51
Carya glabra	64	20	52

Although it is difficult to ascertain if their origin is by mutation or through recombination, many variants in softwoods and hardwoods have been described, and, in some cases, have been widely utilized in landscaping where unusual form or coloration can be effectively used. Rehder (1940) lists seven varieties of Scots pine that are distinctive in needle color, needle length, width of crown, and angle of branch to trunk. In addition to these he lists four geographical races that differ in morphological characters. Nine varieties of Austrian pine are listed that vary widely from each other. Among them is a dwarf globose form and a prostrate form. Wyman (1949) comments there are about 40 forms of Norway spruce and Rehder (1940) lists 32. The latter divides them on the basis of forms differing in color of the leaves; columnar and narrow, pryamidal forms; pendulous or sparingly branched forms; and dwarf forms. Seven varieties of white spruce are listed. Five forms of white pine are recognized. There is a form with light bluish green needles, and another with ascending branches forming a narrow, pyramidal head.

One is a dwarf of somewhat conical compact bush with short needles, another is a dwarf, umbrella-shaped bush with short needles, and one has a dwarf, decumbent form with diffuse trailing branches. Probably many of these variants are mutations. Inasmuch as the horticulturists have been so successful in selecting horticultural forms, there seems good reason to believe that quite as good results might be obtained by selecting for economically valuable characters of interest to the forester.

Hardwoods contain many varieties and offer a fertile field for selection. Rehder (1940) lists four varieties of yellow-poplar. One type, Liriodendron tulipifera fastigiatum, is a tree with upright branches forming a narrow, pyramidal crown. The other three have leaves of distinctive shape or color. Sweet gum has a variety (Liquidambar styraciflua pendula) that is characterized by the deflexed pendulous branches forming an almost columnar crown. Another variety has leaves with three to five short, rounded lobes. Magnolia grandiflora lanceolata has leaves of distinctive shape and a narrow, pyramidal habit. Varieties of many other species have been described, and some of them may be of value to the forester. However, some are described on the basis of a morphological difference of little economic importance. Those that have distinctive and superior form may be superior to wild types for planting. These should be carefully studied with this in mind.

In summarizing this review of the variation caused by mutations, the main point is that some extremes of form may occur through changes in one or more genes and that these desirable or undesirable traits will occur in future generations. Small mutations may cause slight differences between plants that could not be distinguished from the effects of recombination and segregation, while other mutations would cause much larger differences. The effects of mutation may be expressed in many forms because of the large number of ways in which they may take place. Some forms may be valueless for most forestry work while others could be the foundation of valuable types. These types may breed true from seed or some of them might require vegetative propagation. Selection of superior mutants is one way of obtaining better types of trees, and those available now should be studied by foresters.

Variation Between Populations

A number of terms, such as cline (a pattern of continuous genetic variation in geographic space), topocline and ecocline are used to identify groups of plants in which the differences in one or more characters are graded in a definite direction, often with topography or with changes in ecological conditions. Loblolly pine planted in South Africa showed clinal variation in height growth according to latitude of origin (Sherry, 1947). After nine years, the most growth had been made by stock of southern provenance, and total height decreased gradually for the other provenances toward the north. Clinal variation is often associated with altitudinal zones. Cold resistance and photoperiod responses often show clinal variation.

Another set of terms is used to identify groups of plants in which the variations are generally not graded continuously in any definite direction; these are variously called ecotypes (geographic races), varieties, subspecies

and a whole host of others. Such plant groups may vary either physiologically, morphologically, or both, but in any case the variation is not great enough to cause the group to be called a separate species. Ecotypes, varieties, etc., are developed under the influence of natural selection, although occasionally characters are developed that, on the surface at least, have no direct relations to environmental factors. Commonly these variations are thought to be distinct from clines, but usually there is a definite overlap and the two cannot be distinctly separated. The terms used in the above paragraphs are defined in more detail in the glossary.

A number of important conclusions can be drawn from the studies in the United States and foreign countries of seed source effects on growth, form, and other characteristics of forest trees. A summary of these is given in the appendix. The conclusions of most importance are (1) source of seed may have an important effect on growth and yield of pine and hardwood plantations, (2) our knowledge of best sources is insufficient to guide the forestry work in the South.

Other brief conclusions are as follows: Some species have more strains than others; material of southern provenance often grows poorly in the north because of frost damage; some sources are more disease resistant than others because of differences in time of flushing or other traits that hinder infection; it is necessary to determine proper provenance for various climatic areas because material that does well in certain areas or on certain sites may not do as well in others; different races may occur within a few miles of each other and show as much difference in growth as more widely separated areas; the growth of trees from seed collected at lower altitudes may be greater than that collected from higher altitudes; seed of some foreign provenance may grow better than local races; some variation is continuous and the change is gradual over long distances, while others are discontinuous and wide variation occurs within short distances.

The problem of determining which races or strains give the highest volume growth in each of the broad planting regions of the South is a large and important one. With our present knowledge we can use stock of local origin and expect returns that are about average for that area, or we can use seed of some other source and expect to get either average returns, greater returns, or lesser returns.

SELECTION IN TREE IMPROVEMENT

Selection has a definite place in forest tree improvement, and can be carried out in different ways. Hayes and Immer (1942) have outlined the major types of selection as follows:

1. Mass Selection

   a. In self-pollinated crops
   b. In cross-pollinated crops
   c. In dioecious crops (selection of both male and female plants for the characters desired)

2. Individual Plant Selection

   a. In self-pollinated crops
   b. In cross-pollinated crops without control of pollinations
   c. In controlled self-pollinated lines of cross-pollinated plants
   d. In dioecious crops
   e. In crops normally clonally propagated

According to Richens (1945) the methods of selection used in forestry are mass selection, mother tree selection, and individual plant selection. This is essentially the same as given by Hayes and Immer, but with more emphasis on selection of seed from superior mother trees because of the importance of this method in forestry practice. In mass selection, seed from a number of superior trees is collected and planted for several successive generations. No attempt is made to keep the seed separate by individual trees. This is the least precise method of selection because there is no strict control of parentage on either side and the population remains genetically heterogeneous. Roguing nursery seedbeds and immature stands, when making intermediate cuts, eliminates inferior stock and favors perpetuation of the better types. Selection of superior seedlings from nursery beds is a form of mass selection. It has not proven very effective in a test at the Institute of Forest Genetics and other tests in Europe. This technique has not been adequately tested with southern pines, and data applicable to these species are needed.

Mother tree selection consists of choosing satisfactory trees, after progeny tests, and planting the open-pollinated seed for several generations. Seed of each tree is kept separate. There is no control of the male parent in this type of selection, but there is more emphasis on superior individual mother trees than there is in mass selection.

Individual plant selection followed by controlled pollination, using pollen from selected trees, is the most efficient method of improvement because both parents are known. It is the most expensive method, but if precision is required in improving certain traits, it is the most practical.

Selection of superior trees in wild stands and after hybridization is a part of tree-improvement programs in Sweden, Denmark, Canada, Australia, South Africa, Great Britain, and the United States (Sylven, 1939; Lindquist, 1948; Syrach Larsen, 1949; Place, 1951, Fielding, 1948; Philp and Sherry, 1946; Mathews, 1950; Curry, 1943; U. S. Forest Service, 1948; Brink, 1949; Anon. 1950; Ibberson, 1950; and Scanlon, 1951).

Hazel and Lush (1943) discuss the efficiency of three methods of selection, as follows: "The 'tandem method' is to select for one trait at a time until that is improved; then for a second trait; later for a third, etc., until finally each has been improved to the desired level. The 'total score method' is to select for all the traits simultaneously by using some index of net merit constructed by adding into one figure the credits and penalties given each animal according to the degree of its superiority or inferiority in each trait. In the method of 'independent culling levels' a certain level of merit is established for each trait, and all individuals below that level are discarded, regardless of the superiority or inferiority of their other traits." In discussing the features of each method, Hazel and Lush state: 'In all three methods there is always the danger that selection will fall below its maximum efficiency because too much attention is paid to some characteristics and too little to others. In the tandem method that would take the form of selecting first or in too many generations for unimportant things while postponing or selecting too briefly for more important things. In the total score method that would take the form of using too high values for some characteristics and too low values for others, or making mistakes in estimating the heritability so that some characteristics would be thought more highly heritable and others less highly heritable than they actually are; or of failing to consider properly the effects of genetic and environmental correlations between traits. In the method of independent culling levels, the culling level might be set too high for one characteristic, too low for another." They conclude that: "Selection for a total score or index of net desirability is much more efficient than selection for one trait at a time. . . . Selection for several traits by using independent culling levels for each is more efficient than tandem selection for each trait one at a time, the relative efficiency increasing with the number of traits and intensity of culling."

Selection for an index which gives proper weight to each trait will probably be the most fruitful in obtaining improved varieties of trees. Generations of trees are too far apart to select for one trait at a time, as in the tandem method. However, in selecting for disease resistance it may be advisable to attach the most importance to this one character. Before selection will be most effective we will have to obtain data on the economic importance of each trait and its heritability. Selection can then be made for combinations of traits with a high value as indicated by the product of its heritability and its economic value. The total value is the sum of these products.

Hazel (1943) discussed the genetic basis for constructing selection indexes. He reviewed the use of the discriminant function for wheat selection as used by Smith (1936). Hazel presents a multiple correlation method of constructing selection indexes having maximum accuracy for swine breeding. The following constants must be known in order to solve the simultaneous equations:

1. Relative economic values for the different traits
2. Phenotypic constants
   a. Standard deviations for each trait
   b. Correlation between each pair of traits
3. Genetic constants
   a. Heritability of each trait
   b. Genetic correlation between each pair of traits

Other studies in methods of selection are those by Simlote (1947), discussing application of discriminant function for selection in durum wheats, and Robinson, Comstock, and Harvey (1951), who propose a method of separating genotypic and phenotypic variation and construction of a selection index for corn.

Mather (1949) has listed the various factors affecting the speed of the selective progress. Selection may not have the significance within a short period of time in improving succeeding generations of forest trees that it does with annual crops, but the factors that control progress are of interest because they indicate some of the variation we may find between species. We know the genetic make-up of some species is quite different from that of others, and accordingly we should expect some differences between species in the type of improvements that can be made. The speed of selective progress will depend on:

1. Rigor of selection
2. Number of genes, as organized into effective factors
3. Variation in magnitude of action of the genes or factors
4. Their dominance relations
5. Their linkage relations
6. The size of the contribution of nonheritable agents to the F_2 variation
7. The sampling variances of the genotype frequencies in progeny

It has been indicated that selection of superior plants from wild stands and in successive generations of control-bred plants is considered an important part of plant-improvement programs. However, as far as selection of trees is concerned, practically no work has been done toward developing techniques for selection. There is need for studies in natural variation to establish the range of variation for traits of economic importance in commercial species, and, also, to learn the proportion contributed by the environmental factors as opposed to genetic factors. Well-designed progeny tests with material from known parents will provide data on the latter.

Some of the variation in traits of economic importance for commercial species is discussed in the next section.

SELECTION FOR SINGLE TRAITS

Selection will be used by practicing foresters in seed collection and timber marking for both intermediate cuts and the regeneration cuts. In all of these the primary consideration will be for the best traits in combination. In other words, the silviculturist evaluates the entire tree in relation to others in the stand. Other foresters, such as those working in tree improvement or studying natural variation, may be primarily concerned with evaluating individual traits of which there may be a great many, as well as combinations of traits that make trees worth more. These two objectives require somewhat different approaches and will be considered separately. Single traits form the basis for combination, so they will be discussed first.

Selection of superior trees for single traits as well as for combinations will be necessary in tree-improvement work. Selection plus hybridization, involving different species as well as the same species, provides an opportunity for combining a number of superior traits that would never occur under natural conditions. While desirable combination of traits, such as vigor, quality, and resistance to pests, is of some importance, it is not critical. It is much easier to find individual trees that have the extreme of one character than of two or three desirable ones. If found, the latter should be used of course, but to deliberately search for them may be a time-consuming job and not very productive in comparison with results from methods of improving trees by a program of controlled breeding along with selection. In forest stands cross pollination usually occurs between trees that are fairly close to each other. Wind-borne pollen may travel for long distances, but usually the volume is insufficient to cause widespread pollination. Thus, single, outstanding trees, if widely spaced, aren't apt to cross pollinate and produce seed in volume. Buell (1947) collected pollen at distances up to one-quarter mile from a shortleaf pine stand and found at a quarter of a mile about a tenth of the pollen falling within the forest itself can be expected. For the first tenth mile the amount drops rapidly and beyond that distance, gradually. The Northeastern Forest Experiment Station (1950) found that spruce, fir, oak, and pine yielded little viable seed except where trees of the same species were growing close by. For white pine, production of viable seed was only 0.3 to 1.8 per cone on trees isolated from pollinating neighbors by 200 feet or more. Isolated trees may produce seed, but much of it may be empty.

Selection for single traits as part of research permits more choice of areas in which to work, the standards are higher, and the variety of traits studied will be much broader. Careful choice of areas in which to work is of primary importance, and it should be possible to eliminate much of the phenotypic effects by careful selection of stands. The physical features of the area, such as topography, soil, moisture condition, and exposure, should be as uniform as possible. Likewise the stand should be even-aged, and the trees should be evenly spaced. Wider spacings are desirable because competition has less effect on any one tree and also a better estimation of crown form is possible. Planted stands with rather

wide spacing on level, old fields are about the best places in which to work. It is realized that conditions such as these don't occur very often, particularly with hardwood species, because few have been planted. However, there is usually a choice of areas so that the best under local circumstances can be used. If racial variation occurs within the species, the better races should be scouted for superior individual trees to determine the best trees in the best race.

Construction of frequency distribution curves to establish the limits of natural variation is an important part of selection work, until experience is gained in selecting by eye. These curves will reflect mostly genetic variation if the data for them are taken in stands where environmental factors are uniform. Distribution curves indicate the proportion of the population that will fall under various levels of selection, and also the rate of advance under selection if they are skewed. Hazel and Lush (1943) state: "When the population is skewed with the long tail of the distribution toward low merit, progress is faster with mild selection and less rapid with very intense selection than in a truly normal curve. If the long tail of the distribution is toward high merit, the reverse is true--progress is a little less with light selection, but a little more with intense selection."

If the field selections are to be verified, they should be followed through with progeny tests for the final estimation of the genotype. Such tests are expensive and usually only the very best trees can be studied in such detail. Thus, the standards by which trees are selected should be very high. Usually it will be desirable to make a survey of the range of natural variation in the particular characters to be studied so the upper limits will be known. Also, it is possible to reject some trees because of undesirable secondary traits.

Selections may be made for a large number of single traits, especially in the field of wood quality and resistance to fungi and insects. Such studies will require special planning to meet the immediate objectives in regard to species and utilization. The discussion by Koehler (1939) of heredity versus environment in improving wood in forest trees will be helpful to those planning to make selection for quality.

Selection for vigor.--One of the first steps in selecting trees for vigor is to study the range in growth rates for the particular species. There are not many data of this type because in the past the emphasis has been on determining average growth for a stand or area rather than the extremes. The curves for planted stands of slash pine are examples of data of this kind. Figures 17 and 18 show the diameter and height frequency distribution for plantations 8 and 16 years of age. In both cases maximum diameter is about 50 percent larger than the average. Basal area of the largest trees is about 130 percent (2.3 times) greater than that of the average tree. There is also a rather wide variation in total height. Frequency distribution curves such as these are useful to show variation in plantations of southern pines because there is not much variation in soils, as compared with mountainous areas, and spacing is relatively even. All the variation may not be from genetic causes, because planting technique may have been faulty in some cases.

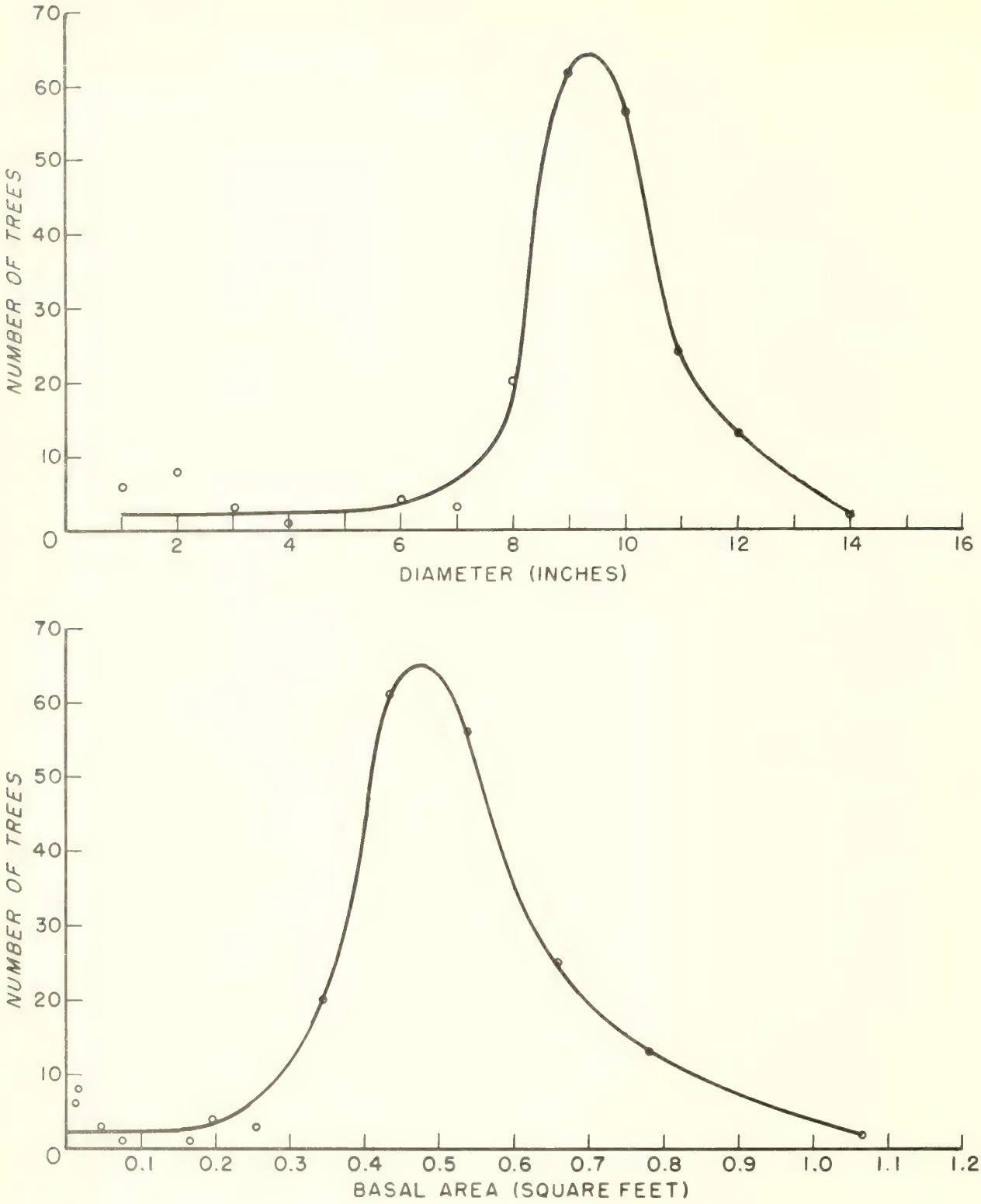

Figure 17.--Frequency distribution curves for plantation slash pine after 16 growing seasons. There are 202 trees on a 1-acre plot. The diameter curve (upper) shows that most of the trees are between 6 and 14 inches, and average 9 inches. The largest trees are 55 percent larger than the average tree. The basal area curve (lower) shows the largest trees are 130 percent larger than the average tree.

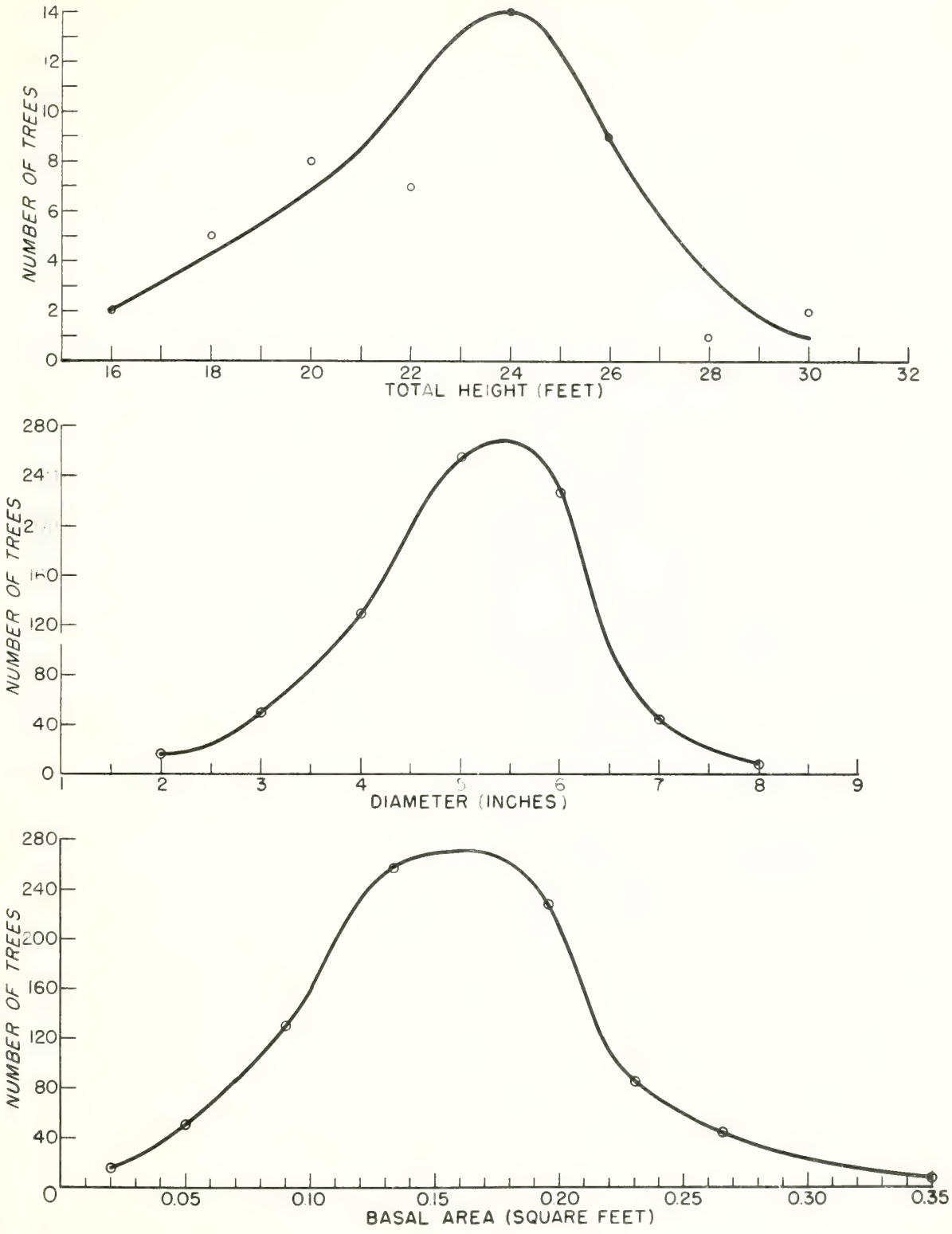

Figure 18.--Frequency distribution curves for slash pine in a 5-acre plantation on a uniform site after 8 growing seasons. The height curve (upper) shows the tallest trees are 30 percent taller than the average tree. The diameter curve (center) shows that some trees are 60 percent larger than the average tree. The basal area of some trees (lower curve) is 130 percent larger than average.

In uneven-aged stands or in areas where site changes rapidly in short distance, other standards for selecting plus trees may be desirable. In Sweden, Scots pine is selected for form and vigor. Some of the requirements, according to Lindquist (1948) are: "As regards the cubic contents, experience has shown that elite stems should have at least 50 percent more volume than the average of the three next biggest trees in the immediate vicinity. In selecting such trees, the slenderness of the branches should be balanced against the vigor of growth, but in such a way that no trees are chosen outside the slender-crowned type, and no selection of extremely slender-branched trees is done outside the fully dominant type." Lindquist also lists requirements for superior hardwood trees of several species.

Regardless of species, the plus trees should be rated on the basis of their superiority over average trees, and the more trees used to determine the average the better, if the site remains uniform. A comparison with 20 or 25 trees on the same site is more reliable than many times that number scattered over a large area where the site varies.

The standards for selecting trees for vigor will be much easier to set up after some progeny tests are made for each species; until then it is a matter of judgment. Standards for superior trees should be high and chosen after some field study of the species has been made. Only a relatively few trees can be used in progeny tests, so only those that are very outstanding should be selected.

Foresters should not expect a tree-improvement or tree-breeding project to remove the need for silvicultural treatment. These two fields of work should supplement each other, but are not interchangeable. Regulation of growing space plus judicious pruning and roguing in thinnings by removing undesirable types are very practical methods of controlling both vigor and quality. This applies particularly to the slow-growth versus rapid-growth controversy. Arthur Koehler of Forest Products Laboratory had this in mind when he wrote. "Wood of very rapid growth of some species has been found to have some very undesirable properties, but that was true for trees that had a large amount of growing space, at least, while young. In a nearly fully stocked stand, I don't think that we need to worry about too rapid growth of individual trees so far as wood quality is concerned, provided the stand is kept well stocked from the beginning. There may be a tendency in managed stands to keep the stand somewhat understocked, so as to get a greater amount of growth per tree. It is there where a question may come up whether too much quality is sacrificed for quantity, and that depends on the species and what the wood is to be used for. Another important factor is to keep the rate of diameter growth fairly uniform within a tree, since wide rings around the center and narrow ones toward the outside do not make for the best kind of wood. So far as breeding timber is concerned, it seems to us that there need be no goal or limit for rate of growth. The faster it will grow per acre, the better; the width of rings and coordinated properties can be regulated by density of stocking."

Selection for quality.--Improvement in quality may be divided into two fields of work. One is that concerned with external characteristics, such as branch size, crown width, stem taper, stem straightness, and pruning ability. The other is concerned with the wood itself where characters such as density,

fiber length, grain straightness, chemical composition, and many others are important. Improving the quality of wood by selection and breeding is an important field of work, and at the same time a rather complicated one. However, it lends itself very well to specialization, and it is here that perhaps the most may be accomplished. It may be easier to separate forms from the wild species that will be better adapted to certain products than the run-of-the-mill wild stock. This will not remove the need for types suitable for all-round use, but there is need for both. It is difficult to imagine one type of hybrid corn that would be as suitable for popping, table use, and fattening livestock, as the three types which we now have, each of which contains many varieties. Specialty woods are probably of more importance for furniture or veneer, pulps or wood derivatives than for lumber.

Not many studies have been made of natural variation in wood quality in the pines, and others will be necessary before much selection or breeding can be done for anything other than volume growth. The demands of the pulp industry may have a bearing on this because of the variety of products they make. The yield of pulp obtained from southern pines ranges from about 95 percent by weight for groundwood pulp to 45 to 48 percent for sulfite and sulfate pulps. The requirements of a superior pulp tree depend on its use. For example, for the production of pulps to be made into paper requiring good formation and smoothness of surface, a good bursting strength and tensile strength, but not high-tearing strength, pine wood containing a relatively high volume of springwood is likely to be more satisfactory than wood containing a high amount of summerwood. On the other hand, for papers and boards in which low porosity and high resistance to tearing are desirable, and smoothness and bursting strength not so important, wood containing larger amounts of summerwood may be expected to give better results. For mechanical pulping and sulfite pulping, fast growth is preferable to slower growth, particularly if the latter contains an appreciable amount of heartwood. Since the yield of pulp on a volume basis increases with the density, it is desirable to produce a wood with as high a specific gravity as possible, commensurate with the other properties desired. Whether or not strains of trees that inherently produce wood of these types, combined with suitable silvicultural practices, can be developed remains to be seen. The veneer industry, under present standards, prefers fast-grown wood with little difference between springwood and summerwood.

The breadth of the field of work in wood improvement is indicated by the summary prepared by Arthur Koehler, of the Forest Products Laboratory, at the request of the division of forest genetics of the Northeastern Forest Experiment Station. The list is repeated in full and gives the characteristics to aim for in breeding certain species.

Straight stems	all species
Minimum butt flare	
Early self-pruning	
Resistance to decay within an economic rotation period	
Rapid height growth for volume and distance between knots	
Rapid basal area growth per acre	
Straight grain (except where figured wood is desired)	

Wide sapwood - Abies, Acer, Betula, Fraxinus, Tilia

Narrow sapwood - Juglans, Pinus (white pine particularly), Quercus

Long fibers - Abies, Picea, and Pinus (This is not so important for paper making as some think it is, because the fibers are broken up more or less in the beater. An increase of 10 percent in fiber length would mean little.)

Figured wood - Acer, Betula, and Juglans (The value of figured wood is so much more for certain species that it should be a lucrative field for tree breeding.)

Density - High density for Abies, Acer, Betula, Fraxinus, and some Quercus. (This could be obtained largely automatically in stands kept growing vigorously by thinning, except in Abies, Picea, and Pinus, in which the density of the wood decreases in rapid growth.) Low density is desirable in Liriodendron, Juglans, Prunus, and some Quercus, on account of ease of working and low shrinkage. Low density and rapid growth per tree in these species usually do not go together. It would be a question as to which is more important.

Strength - High strength for Acer, Fraxinus, Pinus, and some Quercus

Durability of heartwood - Pinus and Quercus (white-oak group only), compare difference between ordinary and shipmast black locust

Ease of surface finishing)
Low shrinkage)
Freedom from excessive warping (sweet gum particularly)) All species
Rapid drying without serious degrade)
Ease of penetration with preservatives)
Ease of pulping and bleaching)

Branching habit may be important in determining spacing of plantations, rate of natural pruning, and the volume of the clear wood in the tree. Slender crowns are preferred over broad, and small branches over large. The reasons are rather obvious and probably not worthy of further discussion. We should remember though, that branch habit should be considered as secondary, and important only as it affects the economic yield of the tree. We don't want to sacrifice vigor or seed production for the sake of having small knots in the wood unless smaller knots will raise the value of the wood product. On the other hand, there is little point in having a lot of volume in large, massive branches if we can obtain good growth without it.

The angle of the branch with the horizontal is of some importance. Where it is large and the limbs extend upward and outward, they do not prune as quickly as horizontal branches that become shaded much earlier. Loblolly pine has this undesirable type of branching and it probably could be improved by selection. The tree in figure 16 is an example of a fairly open-grown tree that is very poorly pruned. Crosses of loblolly pine with longleaf pine usually show the branch habit of loblolly pine, as far as number and form of the branches are concerned, but, in addition, the branches are large in diameter, similar to those of the longleaf parent. Segregation of more desirable types may occur in the F_2 generation which

could be observed by growing seedlings from open-pollinated seed of natural hybrids.

There may be an opportunity to select strains that give higher than average yields of pulp because they have less lignin in the wood. Nilsson (1943) cites cases of variation between trees in the amount of lignin of Scots pine and spruce, and also spruce from different parts of Sweden. In spruce and pine he found differences in chemical composition of the wood, and a big difference in yield of sulphate and sulphite pulp. Resin, lignin, and cellulose varied from 0.52 to 2.73 percent, 26.3 to 31.2 percent, and 48.1 to 55.5 percent. There was some difference in the wood between ramets (see glossary) of some aspen clones, but not as large as between clones. Fiber length was found to vary also. The samples were selected at random, and wider extremes may occur.

Selection or creation of polyploid forms of hardwoods may be desirable. Cells of certain plants which have double the usual sets of chromosomes may be 50 percent larger than in normal types. This has been advanced by Duffield (1943) as a possible cause for some of the variation in wood of red maple and by Wright (1944) for white ash, which contain polyploid types. Johnsson (1950) found in a polyploid-diploid cross of alder that the specific weight of the dry wood was lower. Also, Nilsson (1943) found the cells of a triploid aspen in Sweden were 50 percent larger than those of diploids. Thus, changing the number of sets of chromosomes may be a technique for obtaining types of hardwood trees that form relatively light wood even though they grow rapidly. Unlike pine, rapid-growing, ring-porous hardwoods produce heavier wood than slow-growing trees.

Sylven (1942) reported results of analyses of annual ring breadth, the autumn wood percentage, the volume weight, and the content of resin, lignin, and cellulose of 149 different 70-year-old central European spruces in Sweden. Spruces of different branching types gave similar values, but the breadth of annual ring was demonstratively greater in comb spruce variety than in the brush spruce or the "plane" spruce varieties. The analysis showed the existence of large differances between trees which might well be of importance in breeding for quality. In comb spruce, for example, the resin content varied from 0.74 to 2.14 percent (on a dry-matter basis), the lignin content from 26.3 to 29.9 percent, and the cellulose content from 49.3 to 54.8 percent.

Selection for durability of the wood may be important in species such as the oaks and black locust. From a study of the decay resistance of four white oaks (white oak, Oregon white oak, chestnut oak, swamp chestnut oak) and three red oaks (northern red oak, scarlet oak, black oak), Scheffer, Englerth, and Duncan (1949) concluded that: "Individual trees of the same species, of approximately the same size, and in the same locality differed markedly from one another in resistance. This was true of all four species examined, but especially so of white and swamp chestnut oak. This variability in resistance among trees appeared to be attributable more to genetic differences than to differences in the

environment of the trees. The possibility presents itself, therefore, of selecting and propagating oak trees with wood having not only a longer but also a more uniform service-life expectancy." Hopp (1941) has emphasized the importance of selecting black locust for wood quality. Scheffer and Hopp (1949) tested the decay resistance of shipmast locust, a variety called Flowerfield, and common locust. They found on the average that the Flowerfield strain decayed the least, the shipmast somewhat more, and the common locust considerably more. Black locust has several varieties, and the genus Robini itself is variable in its cytology. Some species have 10 diploid chromosomes, two are triploids with 15 diploid chromosomes, and one race has been reported with 11 diploid chromosomes. Selection should be very profitable in a species where such wide genetic variability occurs.

From a study of the wood from 23 yellow-poplar trees, Erickson (1940) found indications that specific gravity decreased as rate of growth decreased, but rate of growth was not closely correlated with specific gravity. Only 23 percent of the variance of all the samples could be explained by the variation in the rate of growth. For 20 of the trees the regression coefficients were negative values and for the other three they were positive. Thus, it may be possible to select strains of yellow-poplar that grow rapidly and yet produce light wood.

Selection for resistance to disease and insect pests.--Selection for resistance to common enemies of forest trees should have an important place in plant-improvement work. Damage of this type not only causes loss of individual trees but reduces quality and growth and complicates marking for intermediate cuts. Resistant strains would reduce the loss of seedlings in the nursery and throughout the life of the stand, and would result in an increase in total yield of wood per acre. Resistance to certain insects and diseases has been demonstrated to be heritable, and, in some cases, like mimosa wilt, some individual trees developing from open-pollinated seed of resistant mother trees are themselves resistant.

A number of diseases cause large losses in southern pine. Probably most important is Cronartium fusiforme, the rust canker. It is particularly damaging to slash and loblolly pine. Some slash pine trees may be resistant, because disease-free trees have been observed in plantations where 75 percent of the trees are infected. Some of the disease-free trees may be the largest and most rapid-growing trees in the stand. This is in contrast to observations which show that, in general, fast-growing trees, or those fertilized or cultivated, are more susceptible to this disease than slow-growing trees. Rapid-growing trees that have escaped infection in heavily damaged stands should be tested for resistance to the disease.

Selection and breeding for disease resistance has been common in horticulture, and with certain tree species such as chestnut and white pine. The techniques that have been worked out vary somewhat according to the nature of the disease because testing progeny for resistance is a specialized job. In his book, "Principles of Plant Infection," Gaumann (1950) makes the following statement concerning inheritance of resistance in plants: "The innate infection and disease-resistance capacities depend on a number of very heterogeneous conditions. Only seldom do they depend on a single factor, but mostly they are the result of the interplay of heterogeneous elements, such

a resistance to attack, penetration or spread, anti-infectional and anti-toxic defense reactions, and induced tolerance. Accordingly, their mode of inheritance is very complex. Certain factors associated with resistance are inherited, as also are certain functional capacities associated with the defense reactions; the final result (the resistance to disease as measured experimentally in laboratory and field trials) is produced by spatial and temporal cooperation of all these factors. The following facts are basic:

1. Resistance to any one disease is usually inherited as a unitary, genetic complex, entirely independent of resistance to any other disease.

2. For specialized pathogens (and these form the overwhelming majority) the resistance to each single strain is, as a rule, inherited as a unitary, monovalent, genetic complex, more or less independent of the resistance complexes against other strains of the pathogen."

Selection for resistance to temperature extremes --This is an important factor in choosing strains or races for use outside their natural range or near the northern limits. Damage from freezing may occur when seed of southern provenance is grown in northern areas or at higher altitudes. Shortleaf pine from areas in the southern part of its range is injured in Pennsylvania, while trees of local sources are uninjured. We may find that generally in this hemisphere plants may be moved toward the north or from lower to higher elevations and grow more rapidly than local plants, provided they are not moved so far that they suffer from frost damage.

Selection for secondary products.--Some tree species, particularly those producing edible nuts or valuable oils, may be as valuable for these products as for the wood. There are good opportunities for selecting superior types because of the wide variability in the wild stand. The TVA has selected some 42 varieties of black walnuts. The Stuart variety of pecan is a selection that is still popular after many years. Honey locust trees have been selected for higher sugar content in the pods, which are suitable for cattle feed. Sugar maple trees have been selected for high sugar content in the sap.

Selection of slash and longleaf pine for high oleoresin yield is important in the naval stores region, and individual trees producing 2.5 times the average have been found (Dorman, 1950). Laurie (1941) lists 24 species of Indian trees, some of which exhibit individual or racial variation in yield of oil, resin, or other minor products as well as in yield of timber, growth form, and hardiness.

Usual procedure in selection is to itemize the factors of most importance, such as flavor and ease of cracking nuts or kind and quality of certain oils. Individual trees that produce the best are then sought out in wild stands, and the progeny tested to insure that traits are inherent. There is some evidence of physiological races in forest trees, although

the subject has not been exhaustively studied. Scheffer, Lackmund, and Hopp (1944) found differences between trees in the amount of hot-water extractives in black locust wood. In Australia, Penfold and Morrison (1948) found only small quantities of the aliphatic aldehyde citronellal in the essential oil of certain trees of Eucalyptus citriodora, where it is usually present to the extent of 65 to 85 percent. The Queensland Forest Service (1950) summarized additional work to determine the reason for the variation in oil yield and oil quality. Some samples showed a range in yield from 0.2 to 2.0 percent. Normally, the oil is of excellent commercial quality, but that of a few trees showed such a low aldehyde content that it was practically of no commercial value. Guinier (1926) found differences between individual maritime pine trees in composition of resin. Spaven (1949) described the work in Vermont to develop better strains of maple. Certain trees have been found that have 7 percent sugar in the sap as compared with 2 percent of average trees. Also, some trees produced four times as much sap. These are the results of study of sap from 4500 trees. Ferguson (1946) states that quinine content in the bark of Cinchona trees is genetically determined. Chittenden (1950) states that breeding work with rubber trees is directed toward development of types giving a stable latex, and especially a white latex suitable for crepe production as well as high-yielding types with good secondary characters.

The three traits of most interest to the forester in silvicultural work such as timber marking or seed collection are (1) vigor, (2) quality, and (3) resistance to pests. They are the important features of each tree that are discernible in the woods. Also, they are the most important in determining volume and grade of the products which govern financial returns. Quality is used here to indicate form of crown, branchiness, stem taper, straightness, general wood quality, and self-pruning.

Selection for vigor.--Volume growth is probably more important in determining returns than is quality. But inherent vigor is not as easy to manipulate through silvicultural practices as is quality. In this discussion vigor will be considered as a characteristic of the individual tree and not of stands.

Selection of the most vigorous trees in timber marking consists merely of choosing the largest trees consistent with quality. These are the trees that have made superior volume growth in comparison with the average trees on the same site. More variation is to be expected in natural than in planted stands and in mountainous or uneven topography, where soil fertility or moisture conditions may vary within short distances. Spacing of the selected trees to be left in the stand is important, of course, and trees of average growth will be left in many cases because of this requirement. It may be desirable to choose outstanding trees from within a group where comparisons of growth are possible, rather than larger trees in small openings where competition has not been a factor and where it is difficult to compare them with the average because there are few trees in the immediate vicinity. The forester is in a position to rate the individual trees in each particular case because of his knowledge of the effect of superior site or other conditions on the tree growth and development. In each instance, if he chooses the outstanding individual tree on the basis of average growth of a number growing under the same conditions, he won't go far wrong.

When selecting pine seed trees, the requirements or standards can be much higher because only 6 to 10 trees may be left on each acre. In these stands the trees are much older and larger. And because these are the trees that will regenerate the stand, they should be chosen with some care. The same requirements apply that they be the best trees available when compared with others growing under the same conditions, and they should not achieve this superiority at the expense of seed production. The presence of abundant cones from recent crops indicates good producing ability.

In selecting trees from which to collect seed, spacing is less important, and about the only consideration is to keep the collector's travel to a reasonable distance. Also, it is possible to choose the stands from which seed will be collected. Thus, the selection work can be done where it is possible to make comparisons between trees. Fruitfulness of the tree is a requirement in addition to vigor, quality, and

resistance to pests. Von Wettstein (1937) observed that trees of low growth rate frequently produce more abundant cones than rapid-growing strains. The same condition has been found in teak (Laurie, 1936), oak (Anon. 1943), and yellow-poplar (Perry and Coover, 1933). Indiscriminate seed collection favors perpetuation of these mediocre types. Even-aged, uniform stands or plantations in areas where soil conditions are least variable are the best places in which to work.

A few really superior trees are not enough to supply the demand for seed. Moreover, collection from standing trees is not widespread. But over a period of time as the practice increases, it should be possible to have enough outstanding trees selected and marked to supply each year a larger proportion of the annual seed requirement.

Selection for quality.--Quality goes hand in hand with vigor, but on this point foresters and geneticists sometimes disagree because of the close relationship between them. Selection for a combination of traits is most important and comprises the most difficult to make. It is not enough to have fast-growing trees; fast-growing trees must also have high quality. The key to the problem is that we must remember to concentrate on the genotype by estimating and subtracting the environmental effects wherever possible. Open-grown trees are often squatty and limby. The same trees might have grown tall and slender with well-pruned trunks had they been crowded by others of the same species. This means nothing as far as selection value is concerned. If the same individual trees, while in the open, had grown tall and slender with small branches and some natural pruning, it would be a different matter, as this would indicate that they are inherently a good type.

If we select trees in stands without regard to their individual crown size, branch size, crown width, straightness and pruning ability, we are not selecting superior trees; we are selecting trees that are merely big. If we select the most slender trees that have small, narrow crowns and long, well-pruned stems, we may not be selecting superior trees; we may be selecting trees that are merely poor competitors. A superior phenotype is a tree with exceptional vigor, good crown form in proportion to tree size, straight stem, and good natural pruning in proportion to the size of the branches. This is the tree that has demonstrated its superior efficiency by producing the most wood with its proportionate share of light, moisture, and growing space.

Foresters are often hesitant about choosing the largest trees in the stands for crop trees. Many of the large trees present a rough appearance in comparison with other trees which may be much smaller. It should be kept in mind that trees with two to three times the volume of average trees could have proportionately larger branches. The dead branches may not prune as promptly as the smaller branches of other trees, which gives the impression that the crowns of the large trees are much longer than they really are. Good pruning practice prior to the time selections are made will make the large trees very attractive. Inherently vigorous strains are very desirable and should not be sacrificed in favor of quality that can be obtained through good silvicultural practice.

The important external factors in tree quality are:

1. Clear length of stem
2. Taper of stem
3. Straightness of grain
4. Diameter of branches
5. Diameter of bole
6. Forking
7. Straightness of stem
8. Amount of natural pruning
9. Apical dominance (strong central stem in the crown)
10. Flare of the butt
11. Sprouting of epicormic buds

As far as we know, all these are inherent traits, and only trees with the most desirable combinations of them should remain in the stand. The relative importance of each item will vary with species and with the major product the stand is being managed for. The forester can evaluate them in accordance with the local situation. He is better qualified to judge quality than anyone else. If the final product is to be some specialty with unusual requirements, the traits governing them should be of first importance; otherwise the factors that promote high value in trees for saw logs would be paramount.

Selection for resistance to diseases and pests.--This is a relatively simple procedure in the woods. Wherever possible, only healthy trees should be left in the stand. This is true of intermediate as well as final cuts. It is not always possible to remove all the damaged and diseased trees, but they should be discriminated against. Resistances may be phenological, such as those concerned with the period when the tree flushes or begins to grow in the spring. If the new growth of some individual trees or strains and races either precedes or follows the main period of spore discharge of a disease or the emergence of a brood of insects, the new shoots will escape heavy damage. Physiological or morphological differences give rise to other types of resistance.

In summarizing this section on the application of selection, it should be emphasized that a forester in the woods has to work with what he has on the ground at the present time. He can't be, and shouldn't be, concerned with minutiae. If he strives to maintain or improve the vigor and quality of the stock and to reduce loss from disease or pests, he is fulfilling his obligation as a technician. The point is that all variations in form and vigor are not (as foresters so often say) a result of differences in site conditions. Many a poor tree on good soil is the result of poor parents. It is thus unwise to harvest all the best trees and leave the worst to produce the next generation. You can't expect genetically poor mother trees to produce good offspring.

PLANS FOR SELECTING SUPERIOR TREES

Before going to the field and attempting to choose superior trees of any species, it is desirable to take time to plan the operation. The important factors of quality which are influenced by tree form will vary between species. Also, the utilization, or the products made from the tree, will determine what traits are important in superior trees. The important items to be considered in a plan for selection can be listed as follows:

I. Species

II. Products for which the tree is utilized and which may require certain characteristics of form or quality

- A. Lumber or poles (good natural pruning, little taper, small knots, thin bark, good central stem, etc.)
- B. Pulpwood (heavy pine wood for kraft, light for newsprint, yield of cellulose, low percent waste from lignin, knots, and bark)
- C. Furniture or veneer (straight grain, good central stem with little taper, desired sapwood-heartwood ratio, bark thickness, figured grain, etc.)
- D. Other products (fruit, nuts, oleoresin, seed)

III. Important pests

- A. Diseases (foliage, bark, or wood)
- B. Insects (foliage, bark, or wood)

IV. Important uses other than manufacture

- A. Ornamental
- B. Erosion control or soil building
- C. Windbreak

V. Other traits characteristic of the species or the use

- A. Cold resistance
- B. Drought resistance
- C. Fertility of seed as well as volume produced
- D. Growth habit of seedlings

VI. Best areas in which to search

- A. Areas in which best races occur
- B. Plantations
- C. Old-field stands
- D. Virgin stands or second-growth

VII. Traits of which little is known about range of variation

After such a list has been prepared, it is apparent that for most purposes and species, there are only a few major points to rate superior trees. An example of a plan for selecting slash and loblolly pine and yellow-poplar is about as follows:

Slash pine.--(When used for lumber, poles, pulpwood, and naval stores; possible future use for softwood veneer.)

I. Items upon which to rate trees

A. Traits to improve quality for lumber and poles

1. Less taper in trunk
2. Narrower crowns with small branches to give small knots
3. Fewer branches per lineal foot of trunk
4. Less butt swell
5. More ability for natural pruning
6. Thinner bark on fast-growing trees
7. More rapid growth--50% greater in diameter at least--than average

B. Traits to improve quality for pulpwood

1. Same as for lumber except items 1 and 4 above
2. For kraft pulp, high density wood (over .54 specific gravity, high percent summerwood)
3. For newsprint, low density wood (less than .38 specific gravity, low percent summerwood)
4. Higher yield of pulp, lower waste per ton of pulpwood
5. Looser bark

C. Traits to improve quality for naval stores

1. Same as for lumber
2. High oleoresin yields (250 percent or greater of average)
3. Gum of uniform quality throughout the season
4. Less scrape
5. Thinner, softer bark to make chipping easier
6. Ability to produce well on first streaks

D. Traits to improve quality for veneer production

1. Same as for lumber
2. Less variation between specific gravity of summerwood and springwood
3. Better gluing properties
4. Looser bark

E. Traits to improve pest resistance

1. Resistance to fusiform rust, cone rust, pitch canker, needle diseases
2. Resistance to bark beetles and Nantucket pine tip moth

F. Other important traits to select for

1. Drought resistance

II. Best areas or stands in which to search for plus trees

A. Any area near where trees are to be planted (there is not much evidence of racial strains, but the problem has not been adequately studied)

B. Planted stands of good racial stock should have first priority, and even-aged old-field stands second

III. Traits for which little is known of natural variation and which may be important in improving this species

A. Quality of oleoresin (uniformity of yields over different seasons of the year, proportion of important components, such as turpentine, alpha and beta pinene, tendency of gum to form scrape on the tree)

B. Wood density range (between trees and between springwood and summerwood of same trees)

C. Yield of pulp, lignin, and waste products (variation within trees under 20 years of age has been studied) Little known of pulping qualities of south Florida variety of slash pine.

D. Bark tightness (bark should come off very easily; it is not known to what extent this is a variable trait and whether it is genetically controlled)

Loblolly pine.--(When used for lumber, poles, and pulpwood)

I. Items upon which to rate trees

A. Traits to improve quality for lumber

1. Less taper in trunk
2. Narrower crowns with small branches to give small knots
3. Fewer branches per lineal foot of trunk
4. More ability for natural pruning
5. Thinner bark on fast-growing trees
6. More rapid growth
7. Stronger, more pronounced trunk in crown region (strong apical dominance)
8. Larger angle between branch and trunk (branches more nearly at a 90-degree angle with the trunk should be preferred; this is to aid in natural pruning)

B. Traits to improve quality for pulpwood

1. Same as for lumber except item 1
2. For kraft pulp, higher density wood
3. For newsprint, lower density wood
4. Higher yield of pulp, lower waste per ton of pulpwood

C. Traits to improve quality for veneer

1. Same as for lumber
2. Less variation between specific gravity of springwood and summerwood
3. Better gluing properties
4. Looser bark

D. Traits to improve pest resistance

1. Resistance to fusiform rust, cone rust, needle disease, littleleaf
2. Resistance to Nantucket pine tip moth, and the bark beetles

II. Best areas or stands in which to search for plus trees

A. Areas in which best strains occur for planting in designated areas
(Many racial strains occur in loblolly pine, and it is important that selection be made within the best races. If best races are not known, make selection near where seed is to be used.)

B. Plantations of good racial stock even if original source is unknown
(Knowing the source is important, but not an absolute requirement if the plantation is of good quality.)

C. Even-aged second-growth or original old-growth stands

III. Traits about which little is known of natural variation and which may be important in improving this species

A. Wood density variation
(between trees and between springwood and summerwood within the same tree)

B. Yield of pulp and waste materials per ton of pulpwood for various age classes of merchantable trees

C. Bark tightness

Yellow-poplar.--(When used for lumber and furniture veneer)

1. Items upon which to rate trees

A. Traits to improve quality for lumber

1. Figured grain
2. Less epicormic sprouting
3. More rapid growth
4. More ability for natural pruning
5. Both high and low density of wood

B. Traits to improve pest resistance

In this species, susceptibility to major pests is not yet an important factor.

C. Other important traits to select for

1. Higher fertility of the seed

II. Best areas or stands in which to search

A. Plantations of good racial stock

B. Second- and old-growth stands

III. Traits of which little is known of variation and which may be important in improving this species

A. Wood density
(In natural stands density varies widely and the causes are unknown. Paul and Norton (1936) have stated the wood is about twice as variable as that of hard maple. This may be a result of a more heterogyzous nature or from polyploidy which is thought responsible for variation in ash. The occurrence of polyploid types has not been studied.)

MARKING SELECTED TREES

It is very important that selected trees be marked and their location accurately described so they may be easily found again. In addition, they should be described in such a manner that comparison of good and poor traits can be made in the office. One of the most desirable features of a uniform numbering or identification system is that it can be understood by different workers.

The individual tree will be the common unit in selection work. They can be marked temporarily with white cloth and later on by light-colored paint or metal tags. Bands around the trees are easily seen from all directions, although they may be unsuitable for trees near inhabited areas. Several bands may be used to indicate the relative value of the tree or the degree to which it has been used in the tree-improvement work. One band may indicate a first selection, two bands those tested with open-pollinated seed, three bands those used in controlled breeding, and four bands those proven to be genetically superior trees.

Some Swedish tree breeders refer to selected trees as "plus" trees until the genotype has been determined. If they prove to be superior genotypes they are called "elite" trees. A more precise method would be to call untested superior phenotypes "phenotypically elite," and progeny tested trees that are indeed superior genotypes "genotypically elite."

The Institute of Forest Genetics uses a simple and effective system of numbering trees. Metal tags carry the data and are nailed to the tree with long nails driven only part way in to allow for tree growth. The tag gives the abbreviated Latin name of the species, the county and state, the plot number, and the tree number within the plot. Trees more than a quarter mile apart are given different plot numbers, and a plot can be one tree or several trees. In local studies or projects the plot and the number would be sufficient for identification, but if seed or grafting material is sent to other sections the full code should be used. The designation "PC, Harris, Ga., 3A, 4" would mean "slash pine, Harris Co., Ga., plot 3A, tree number 4." If metal tags are unsatisfactory, paint can be used.

Southern pine species abbreviations used by the Institute of Forest Genetics:

	Abbreviation
Pinus caribaea (slash pine)	PC
P. clausa (sand pine)	PCla
P. echinata (shortleaf pine)	PE
P. glabra (spruce pine)	PGl
P. palustris (longleaf pine)	PPa
P. rigida (pitch pine)	PRi
P. serotina (pond pine)	PSe
P. Sondereggeri (Sonderegger pine)	PSon
P. taeda (loblolly pine)	PT
P. virginiana (scrub pine)	PV

Abbreviations for the 90-odd species of pine are available from the Institute, while those for other species will have to be prepared by workers in the South. New symbols should be added only by joint action of all agencies with the Institute.

A detailed set of notes on the characteristics of each tree should be taken. The attached form can be used to suggest the points to be noted. A sketch map of location can be made on the back of the form. If possible, a photograph or sketch of the tree should be included. If progeny tests are made, a record of seed collection, outplantings, and performance of seedlings can be included. Standardization of a record-keeping system will avoid confusion among workers. If additional data can be taken, a sketch can be made showing summerwood and springwood in the increment core; also descriptive data for average trees in the stand, so that a comparison can be made between the study trees and others. Bark thickness, stem taper, branch length, branch thickness, crown length, crown density, and crown width will be useful items of information.

A somewhat similar form can be used in recording data for phenotypically elite stands. The characters of form, vigor, or others that vary from average in the species should be recorded; also the location of the stands so they can be found by other workers. If a large number of selections are made, it may be advisable to transfer the data to punch cards.

CATALOGUE OF SUPERIOR TREES

Species _____

Local number _____
(Plot and tree number)

Description of tree:

Age _____ Heigh _____

Diameter _____ Sex _____

Is there evidence of flower or seed production? _____

Superior traits:

Vigor _____
(Percent taller, larger diameter, or greater volume than average)

Branches _____ Crown _____
(Larger, smaller, or average thickness) (Wider, narrower, or average width)

Straightness of grain _____ Specific gravity of wood _____

Percent summerwood _____ Angle of branches from horizontal _____
(Larger, smaller, or average)

Pest resistance _____
(Damage by insects, diseases, mechanical breakage)

Other traits _____

_____

Location:

Section, township, range, lot etc. _____

County and state _____

Name and address of owner or others _____

_____

Elevation _____

Identification marking on the tree _____

_____

Name and address of reporter _____

_____

Record of seed collection: _____
(date and seed lot number)

_____

_____

_____

_____

Progeny tests or tests with grafts or cuttings: _____
(date, location, experiment number)

_____

_____

_____

_____

Photograph or sketch

(show form and size in comparison with adjacent trees)

Map of location

NAMING IMPROVED STRAINS

Tree breeding and selection projects will probably develop plant material that will be difficult to name under the present methods of nomenclature. Also, it will be undesirable to give formal names to many varieties, variants, or hybrids that may be of value only in experimental work and which will never be used commercially. The book, "Standardized Plant Names," discusses the nomenclature of plant material other than species, varieties, and races, and it should be used as a reference.

At present, races of trees are not given formal names but they are called by a common English name which is usually descriptive. Examples would be the "red-barked" or the "pointed-crowned" races of Scots pine. Natural varieties have been recognized by adding a Latin varietal name to the specific name (see "form" and "variety" in the glossary). Some taxonomists prefer to limit recognition of varieties to those cases where the plant is found over some geographic area rather than to one plant. The way to avoid confusion is to identify a selected strain or variety by the name of the individual, or a number, and avoid Latin names altogether. A strain of slash pine selected by John Doe would be known as Doe's slash pine. This system could also be applied to lots of controlled pollinated seed of superior strains. Some plant breeders prefer to call vegetatively propagated strains by English names and sexually propagated strains by number.

"Standardized Plant Names" suggests some terms for identifying vegetatively propagated clones. A clone is defined as a group of organisms composed of individuals propagated vegetatively from a single original individual. An ortet is the one original plant from which a clone ultimately derives. A ramet is an individual member of a clone. These terms apply to grafted plants or rooted cuttings and not to sexually reproduced types. The term "polybrid" is used as a group name for hybrids from crosses between two particular species, varieties, or genera.

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APPENDIX

Summary of Studies in Racial Variation

The following sections summarize some of the published data regarding clinal and other types of racial variation in the tree species of the United States and in foreign countries.

Races of trees in the United States.--In a 22-year-old test planting at Bogalusa, La., loblolly pine of local source produced a much higher volume per acre and was injured less by disease than that from other provenances (Wakeley 1944, 1951). The native Louisiana stock produced 41.8 rough cords of merchantable pulpwood per acre in trees 5 inches and larger in diameter at breast height. Texas stock had produced 22.7 cords, Georgia 17.7, and Arkansas 15.4 cords per acre. Thirty-seven percent of the trees from Georgia seed had rust cankers on the stems, while only 4 to 6 percent of those from other sources were infected.

From the preliminary results of a test begun in 1935 in South Africa with loblolly pine of different provenances, Sherry (1947) states there were several latitudinal topoclines. Growth of trees from southern latitudes was the most rapid, and was slower from northern sources, but the form of the slower growing trees was better.

The height of the trees in relation to latitude of the provenance is given in figure 19. The three seed sources between latitude 30°N and 31°N were Leon County, Fla., Montgomery County, Texas, and St. Tammany Parish, La. The northernmost seed source was Wisconsin County, Md., which is at 38.4°N.

Seedlings of the same sources were also planted at several places in the United States. At Athens, Ga., the average heights were between 31 and 35 feet, showing much less variation with provenance. At Jasper, Texas, they were between 29 and 34 feet (Wakeley, 1951). Thus, in South Africa, Texas, and Georgia the least adapted stock made 57, 85, and 89 percent, respectively, of the height growth of the best adapted.

In this same study of geographic races, in loblolly pine, infection by fusiform rust was associated with seed source. Wakeley (1951) states, "The North Carolina stock had 22 percent of all living trees infected at both Athens, Ga., and Jasper, Texas. The South Carolina stock had 8 to 16 percent infected at the same two places. Two western strains, those from the Kisatchie National Forest in Louisiana and from Trinity County, Texas, showed only 3 and 1 percent infection, respectively, at Athens, and 7 and 2 percent at Jasper. These results parallel those from the Bogalusa study, in which the one eastern strain of loblolly (Georgia) was more heavily infected than the 3 western strains (Louisiana, Arkansas, and Texas). But strains from northeastern sources, which were not tested in the original Bogalusa study also proved relatively unsusceptible in the 1935 study. Virginia stock was infected only 4 percent at Athens, only 6 percent at Jasper, and Maryland stock showed no infection at either place."

Slash pine has given rather uniform results in the tests made up until now with seed of different provenances. This species has a more limited range than the other major southern pines. If the south Florida type of slash pine

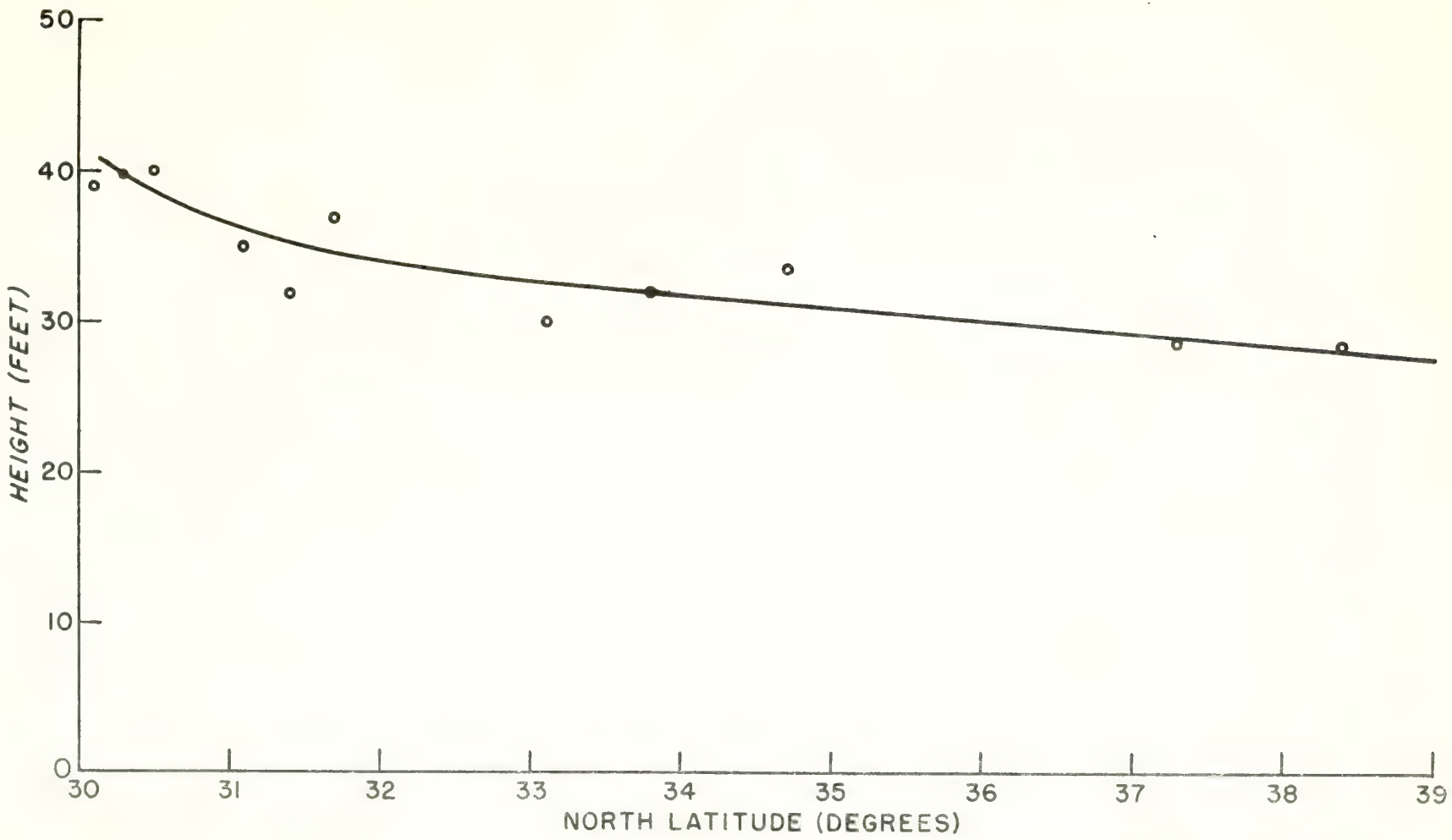

Figure 19.--Height of loblolly pine (growing in Africa) in relation to latitude of seed source (United States)

is excluded, the natural range of the species is between latitudes 27°N and 33°N. Seed from sources between the latitudes 30.1°N and 31.0°N were tested with loblolly pine in the South African study. The results as found by Sherry (1947) for the 9-year-old test show the average heights of plots of different provenance were between 35.7 and 37.8 feet.

Slash pine showed less variation in height growth between tests in four different locations in Africa than did loblolly pine. This may be site effects, but slash pine was remarkably uniform over the entire range when planted at 25°S, 28°S, 29°S, and 31°S. At two locations it was planted at elevations of 150 feet and at the fourth at 3,000 feet. The stock of Liberty County, Fla., provenance differed in height only 1.9 feet between the 4 areas. Stock of Osceola National Forest in Florida varied 5.3 feet, which was the widest range. The average of all 6 sources was 3.7 feet. The average for loblolly pine planted at the same location was 9 8 feet. Variation was less for southern provenances, averaging 7.7 feet for the three sources and 13.4 feet for the two northernmost sources. This indicates loblolly pine stock of northern provenance was more sensitive to local conditions than stock of southern provenance.

Both slash and loblolly pine were rather similar in one other respect in that there was little difference in their rating according to total height at the four test areas. The provenances showing highest average height growth were superior in all test areas--the provenances showing poor growth were poor on all four test plots. No data concerning volume, wood density, or pulp yield are available. Complete data will give a more accurate evaluation of the sources, and these will no doubt be available later.

When shortleaf pine from southern parts of its natural range was planted in Pennsylvania, which is near the northern limit, survival was low and growth very slow in comparison with stock of local origin (Aughanbaugh, 1950). The data for the stock of six sources is given in table 3, as follows:

Table 3.--Survival and growth after 14 years of shortleaf pine of different provenance planted in Pennsylvia

Source of seed	Trees living	Average height	Average diameter
	Number	Feet	Inches
Morgan County, Tennessee	57	14.3	2.7
Stone County, Arkansas	21	11.4	2.3
Houston County, Texas	6	11.3	1.7
Sabine Parish, Louisiana	1	10.0	1.5
Adams County, Mississippi	2	9.5	1.0
Edgefield County, South Car.	5	9.2	1.6

The seed germinated well, but survival was low. Growth of the 80 trees in each lot was very slow and they suffered from frost injury. Trees from seed of Morgan County, Tenn., which has the climate closest to Pennsylvania conditions,

showed definite superiority over others from lower latitudes and altitudes. There were some differences in form of stem between Arkansas and Texas stock. The heights of both were nearly the same, but the diameter of the Arkansas stock was 2.3 inches and the Texas stock 1.7 inches. Results to date indicate that local seed is much the better for planting in Pennsylvania.

There is some additional evidence of racial variation in shortleaf and loblolly pine as indicated by variation in size of pollen grain and strength and weight of the wood. Cain and Cain (1948) measured pollen grains from 27 samples of shortleaf pine collected at various points between Texas and New York. The grains had an extreme variation from about 42 to 70 microns. They state, "The study of Pinus echinata shows what is coming to be expected of size characteristics of morphological features in general, that is, a considerable intraspecific variability. Some collections from stations considerably removed from one another may be very similar. Other material from one locality may be significantly different."

In shortleaf and loblolly pine, weight and strength of the wood varied with the locality where it was grown, but in slash and longleaf pine they did not, according to Johnson and Roth (1896). In shortleaf pine wood from the southern coast and Gulf region and even Arkansas was generally heavier than wood from localities farther north. Very light and fine-grained wood was seldom found near southern limits of the range, while it is almost the rule in Missouri, where forms resembling the red pine are by no means rare. Concerning specific weight, Johnson and Roth state, "Though occasionally some very exceptional trees occur, especially in loblolly and shortleaf pine, the range in specific weight on the whole is generally within narrow limits."

Racial variation in spruce, pond, sand, Virginia, and pitch pine has not been studied. These are minor species in the South and planted only rarely. Races may occur because most of them have rather broad geographical ranges. Sand pine that grows only in Florida seems to vary in the date cones open. In January, most of the trees in the western part of the State had open cones as compared with only a few in the southern part.

Growth of red pine varied somewhat between provenances in a 16-year-old plantation in northeastern Minnesota, reported by Rudolf (1948). Seed of 37 origins throughout the Lake States and including two localities in New England were planted in the Superior National Forest. It was concluded that: "For best assurance of success, collect red pine seed from inland northeastern Minnesota localities, avoiding trees with thin foliage Do not use red pine seeds from New England, lower Michigan, central Wisconsin, or the south shore of Lake Superior. If northeastern Minnesota red pine seed is unobtainable, second choice should go to northwestern or north-central Minnesota or northeastern Wisconsin." White spruce planted in the Nicolet National Forest in Wisconsin by the Lake States Forest Experiment Station(1947) showed difference in growth between the 6 seed sources tested, and seedlings of three provenances in Ontario, Canada, were best. This is interesting because northern provenances planted farther south did better than the local provenance.

In a test of ponderosa pine (Weidman, 1939), seed from 20 origins were planted in northern Idaho. The sources of seed were in western United States and Canada. The best strains made more than twice the height and diameter

growth of the poorest. Two introduced strains, one from the Lolo and one from the Bitterroot National Forests in Montana, grew better than local seed. Munger (1947) reported results after 20 years' growth of ponderosa pine. No systematic observation of the morphological differences in the several lots was made, but even casual comparison revealed marked differences. Some lots were bushier than others, and the color of the foliage, time of needle retention, and the angle of the needles to the twig varied. Needle length ranged from 4 inches in one lot to 7-1/2 in another. On the basis of total height on all six plantations three sources appeared to be best. These three were not consistently best on all plantations, nor were they superior in the plantations most like their locality of origin. Two lots, one from western Oregon and one from western Washington, which are considered the same physiographic region, ranked quite differently. Lorenz (1949) found differences after 5 years of growth between 10 different seed sources of ponderosa pine planted in Illinois. Major differences in color and texture of needles and slight differences in general over-all form could be observed.

Douglas-fir is an important tree in this country, and it has been widely planted in Europe for a long time. Consequently, much has been observed of its variation throughout the natural range. As early as 1913 Zon (1913) reported differences in height growth and form of plantations of different seed source planted in Europe. Since that time, as indicated by Bornebusch (1939), European foresters are very careful to plant Douglas-fir from sources known to produce seed suitable for their area. Peace (1948) discusses the literature of racial strains and the various species and varieties set up by taxonomists. As a result of his own study of the variation within the species, he states, "One is faced, therefore, with two alternatives: either to split Douglas-fir into a very large number of species or varieties, whose ranges would be completely overlapping, or to admit that the tree is a complex of variables between two extreme types approximating to the former conceptions of P. douglasii and P. glauca, and to make no attempt at further botanical distinction. The author is entirely in favor of the second alternative." In summarizing his review of the studies of racial variation in Douglas-fir, Isaac (1949) states: "Various wild strains of the tree have distinct climatic and soil limitations; seed from such strains should not be used beyond these limits. There is also ample proof that superior growing strains exist and it pays to plant the best seed that can be obtained for a given area."

Hardwood species may show racial variation throughout their natural range in this country, as indicated by a number of studies. White ash is one of them, as reported by Wright (1944). On the basis of his study of the progeny of 155 trees from 28 localities in eastern United States and Canada, grown at Petersham, Mass., white ash shows at least three ecotypes:

1. The northern ecotype, which grows from Michigan to central Pennsylvania and New England, and northward; trees are diploid, show little winter killing, have a bushy root system, and lack any pronounced pubescence or anthocyanin development.

2. The intermediate group, which is found in a narrow belt through southern Pennsylvania, northern West Virginia and Ohio, trees

are characterized by a moderate amount of winter killing, bushy root systems, high incidence of pubescence, and lack of anthocyanin development.

3. The southern ecotype, which is found from Maryland to southern Indiana and southward; trees are very susceptible to damage from winter cold, and have tap roots, reddish petioles and leaves which are glossy above and pubescent below.

Of 54 trees of intermediate or southern origin for which chromosome counts or stomata measurements were made, 33 were diploids, 8 were tetraploids, and 13 were hexaploids.

Considerable variation was found in red ash, but the variation within the progeny of any one parent was much less than in white ash (Wright, 1944a). The progeny of 20 trees from 9 localities showed the species to be composed of at least three ecotypes:

1. The northern ecotype is found in Maine, Michigan, Wisconsin, and Minnesota, U.S.A., and Ontario, Canada, and presumably throughout the species range to the north; its southern extent is unknown. Progeny were slow-growing and winter-hardy, and lost their leaves early in the autumn.

2. The southern Coastal Plain ecotype was represented by collections from Virginia, North Carolina, and South Carolina. The seedlings were very subject to winter killing, were significantly taller at the end of the second year than those of 1, and were relatively more susceptible to deer browsing than the rest of the species

3. The New York ecotype is intermediate between 1 and 2, with respect to winter hardiness and height growth.

It is believed all ecotypes are diploid. Also, Meuli and Shirley (1937) collected seed of red ash from 83 localities in the Great Plains region and grew the seed in northern Minnesota. They found the young trees to belong to three genetically different populations. Each was distinct as to geographic range, drought resistance, growth rate number of leaves per plant, and leaf coloring.

A biometrical study was made by Anderson and Hubricht (1938) of the leaves of sugar maple (Acer saccharum Marsh) from groves in various parts of the United States. The New England population seemed to vary about a single plexus, A. saccharum proper; those of southwestern Michigan had two almost discontinuous centers of variation, A. saccharum proper and A. nigrum Michx. f., while groves in southern Missouri and southern Illinois either resembled those in Michigan or else had no recognizable center of variation. Wright (1949) observed local genetic variation in silver maple. Seedlings from open-pollinated seed from nine wild trees in four different localities of Indiana after 2 years showed no significant differences in height or diameter, but did show marked variation in branchiness and frost tenderness.

Black locust has been known for its variability for a long time. Inasmuch as two-thirds of all the hardwood planting in the Southern states is of black locust, it is important that seed of good source be used. Morrison (1935) and Raber (1936) describe a variety known as shipmast locust, growing on Long Island, New York, that is tall and of good form. It differs in bark, stem and flower characters, and in the exceptional durability of wood in contact with soil. It produces very few seed, however, and is usually propagated by root cuttings. The Central States Forest Experiment Station, Schreiner (1938), started work with 22 strains in a search for strains resistant to locust borer. Minckler (1948) reported that the shipmast strain showed no superiority in growth and form to local common black locust when planted in the uplands of southern Illinois. Hopp (1941) found wide variation in the form of open-grown trees in eastern United States. He divided them in to pinnate, spreading, and palmate growth forms. Two or three forms may grow side by side within short distances. A distinctive strain has been found in Randolph County, West Virginia (Anon. 1948). The trees are in scattered stands of tall, straight trees superior to others in the county. They produce seed, while the shipmast strain is very poor in this respect. They come true to seed even when grown in other localities, and have been named West Virginia locust.

In Populus species of various geographic origins, Pauley (1950) found marked variation between clones, which he attributes to genetic differences. Many variations concerned time of cert in physiological functions, especially leaf emergence in spring and growth terminati n and leaf fall in the autumn. P. trichocarpa clones from Alas finished growth in the latter part of August at the latitude of Boston, whereas those of southern Oregon origin remained in active growth until the middle of October. All clones of far northern origin were uniformly dwarfed when grown in the shorter day of the Boston latitude. Other apparent ecotypic variables include growth rate, branching habit, stem form, leaf and bark colors, leaf shape, and resistance to Melampsora rust.

Races of tree species in (or from) foreign countries.--Many provenance studies have been made in Europe and other areas because of the importance of planting in their forestry work. This is particularly true of countries that have few native species and have to import seed of other desirable species. Experience has taught that success of these plantings depends upon obtaining seed of correct provenance. It is for this reason that during recent years foresters from Australia, Sweden, Denmark, and Norway have traveled in the United States studying racial variation and individual tree variations. They hope to obtain the best stock for planting in their countries.

Scots pine has been studied for a number of years and has shown itself to be extremely variable. These studies are reviewed because of the value they might have in planning similar studies in this country. Dengler (1938) studied Scots pine of foreign provenance in the second generation. Although the source of pollen had been impossible to establish with any degree of probability, the second generation showed a good general agreement with the first, and the several races continued to differ among themselves in the characters mentioned. In addition, the second generation varied in straightness of stem, needle characters, and anomalies of bud formation. According to Dengler, Munch was unable to find evidence of acclimatization in the first generation, and according to

the present study no such tendency is observable in the second. In New York, Littlefield (1939) found 5-year-old trees of Scots pine showed marked differences in height growth between trees of Belgian, Baltic, German, and Nebraskan provenance. Gavris (1939) reported on selection of rust-resistant forms of Scots pine in Russia. Seedlings grown from the seed of mother trees that produced comparatively heavy seed were relatively immune, and the degree of immunity was generally higher in seedlings with six to eight cotyledons than in those with four to five. In two lots of seed where weight of 1,000 seed was about 4,000 grams, infection was 44 and 39 percent; where weight was 5,700 and 5,780 grams, infection was 12 and 19 percent.

Lindquist (1940) describes two main races of Scots pine in Sweden: a narrow-crowned race that predominates in the north and a broad-crowned race occurring more commonly in the south. Tiebe (1940) studied specific gravity and crushing strength of the wood of Scots pine from eight countries in Europe. Frequency curves for specific gravity were constructed for a large number of samples. It was shown that the curves for individual stems were mostly the same or at least similar within a race and differed from those of other races. Two subraces occurred in both material of Scottish and Belgian provenance. Specific gravity was shown to be a function of the assimilation capacity of the crown. Heavy and light stems were found within a race. Wood from the French and one subrace of Belgian trees was the heaviest, and varied little within individual stems, that from the Brandenburg, Belgian (the second subrace), Scottish and East Prussian races was medium heavy but varied within individual stems; that from the Perm race was also of medium weight, but varied less; and that from the Kurland and Perm races was the lightest and varied little. The investigation showed that the difference in the specific gravity of wood from individual stems was not traceable to the influence of the habitat. Comparison of figures for crushing strength indicated that in spite of individual variation there were considerable differences between the races in this respect, also. Burger (1941) found differences in specific gravity between races in a test of 32-year-old Scots pine trees of different provenance grown at three different elevations in Germany. When the weight of fresh needles required to produce a cubic meter of stemwood was computed, it was found that pines of different provenance grown on the same site required different amounts of needles to produce the same increment. The density of oven-dry wood grown on the same site varied with the race. Sylven (1940) reported a latitudinal topocline in Scots pine in respect to photoperiodic response. Wagenknecht (1939) investigated a north-east, south-west topocline concerning bark; the north-east forms had a smoother bark than the south-west ones.

In the Vosges mountains in France (Anon. 1941), two forms of Scots pine have been observed. One is a mountain form and the other an intermediate one. Imported strains are grown on the plains. Jacques (1941) describes a very superior race of Scots pine found in the Forez mountains of the Central Massif. Francois (1947) describes the superior race of Scots pine of St. Die in the Vosges. It can be divided into three varieties, distinguished by different types of bark. Hess (1942) describes a gray-barked and a red-barked race. The former occupies chiefly the dry slopes of the Rhone Valley up to 1,000 meters' elevation, and is characterized by slow height and diameter growth, strong branchiness, a flat crown, and very narrow heartwood. The red race is widely distributed at elevations of 1,000 to 2,000 meters. The

trees reach a height of 25 meters, and a d.b.h. of 60 centimeters, have clean boles, a pointed crown, and the stems contain wide heartwood. The growing stock often exceeds 300 cu. m. per hectare as compared with 100 cu. m. per hectare of the gray-barked race. The gray race is fit for firewood only, whereas the red race furnishes good timber.

Schmidt (1943) gives the results of experiments, based on observations of 3 million Scots pine from all the German regions of provenance planted in 12 large plots. The various provenances were compared on the basis of sensitiveness to light, disturbances in racial development caused by climate or human agency, plant-substance production capacity, length of trunk, density of stand resistance to needle shedding, branchiness, faulty and oblique growth, and wound-healing capacity. Meyer (1944) reported on the narrow, pointed-crowned forms of Scots pine in Prussia. Heimburger (1945) found that for direct use under the conditions at the Petawawa Forest Experiment Station in Ontario, the best strains of Scots pine are those from East Prussia, Latvia, and Poland. Rudolf (1948a) examined Scots pine plantings in the Chippewa National Forest during the winter of 1947-48, and found winter injury to foliage varied greatly according to seed origin. Trees grown from seed native to localities in the same climatic zone as the Chippewa National Forest were largely uninjured, but those grown from seed originating in milder climate had a large part of their needles killed.

Van Vloten (1949) gave results of measurements on 21-year-old Scots pine of different provenance. The revealed great differences in growth among trees of different provenance, Dutch as well as foreign. Some imported strains were equal in quality to the better home-grown strains and may be useful for selection and tree-breeding purposes. Scamoni (1950) analyzed the F_2 of artificial crosses between Scots pine of different regions and varieties. The height growth of the trees of the crosses showed in the F_2 the same behavior as in F_1. Crosses of different origins, which in the F_1 showed a certain heterosis in growth, did not maintain this heterosis in F_2, but they tended to occupy an intermediate state between the parents. The bent-stem form of the southwest German pine was dominant in crosses with the straight stem forms of east German origin, whereas the better stem form of the French pines showed an intermediate behavior.

In Europe, Austrian pine (Pinus nigra) has been found to consist of several varieties, as reported by Delevoy (1950), who analyzed sample plot data of several provenances at different stations in Belgium and found small differences in height. The Corsican provenance is somewhat the more productive on good soils, but the Austrian provenance should be very profitable on poor marginal soils.

Norway spruce has been found to have a number of geographical strains. Rubner (1941) found spruce of the plate type--having a layered crown structure because the branches of the first order extend rigidly at a right angle to the stem--growing at two localities of the Bavarian Alps. Burger (1941) gives the results of a 40-year-old plantation of spruce of two provenances grown at two locations. At one location one of the races had much better height and diameter growth, but at the other the two races showed the same increment. One test planting was at an elevation of 470 meters and the other at 1,600 meters. Bornebusch (1941) gives data for 22

years of growth of Norway spruce plots of eight provenances planted in Denmark. Minimum growth was made by the Steinkjer, Norway, provenance and was 109 cu. meters, or 5 cu. meters per year. Best was Ghuringia, Germany, 220 cu. meters or 10 per year. The Danish Grib Sko provenance is relatively late in flushing and less susceptible to night frost in spring than other strains. It is recommended for districts with comparatively severe climates, whereas for the middle regions the Ghuringian provenance is preferable, though seed of good Danish or central European provenances can also be used. Average height data for spruce of different German provenances grown at Tharandt, after 7 years ranged from 40 to 88 cm., Rubner (1944). The height growth of seed from the higher elevation was relatively less than that of seed of other provenances in the same forest area. It appears that the elevation line, dividing fast- and slow-growing races, varies for the different mountain regions, being relatively higher in the more southern mountains of Germany. There was no evidence of a gradual decrease in height growth with increase in elevation of the provenance. Heimburger (1945) found that at the Petawawa Forest Experiment Station in Ontario, the best strains of spruce were those from Valea Mare, Roumania, from northern Germany and the Black Forest, besides the progeny of selected trees of a plantation already established at the Station. Baldwin (1949) reported differences in growth of Norway spruce of a number of European provenances planted at Fox Forest, New Hampshire, in 1933 to 1938.

In studies of European larch of different seed origin, Rubner (1941a) reported on a study of a 10-year provenance trial in Germany. Seed was obtained from various regions of the Alps eastern Sudeten country, higher and lower Latra. Poland, and Scotland. The fastest early growth was made by the Sudeten race. Larches from the lower altitudes in the Alps made good growth, those from intermediate elevations made slower growth, while those from high altitudes were distinctly slow growing. Von Wettstein (1942) found, in small-scale investigations with larch seed from different altitudes and aspects of the Gschnitz valley in northern Tyrol that seed from over 1,500 meters' elevation produced at the end of one growing season stock having on an average about half as many needles as that grown from seed from 1,300 to 1,500 meters altitude. Seed from southern aspects produced stock having a higher dry-matter content than did seed from northern aspects. Dengler (1942) gives an account of investigations on 7- to 9-year-old trees of seven provenances of European larch. Two Sudeten provenances and one from Silesia gave the best height growth. The stem form was good in all provenances, but best in the Weiner Wald. The color of the female flowers of the two Sudeten provenances and of the Silesian and Schlitz provenances was frequently green instead of red or rose. Schreiber (1944) found differences in bark percentage and heartwood formation in local races of European larch. Auer (1946) from his studies in Switzerland found that the present results show--in addition to the unexpectedly large differences in growth, at least in youth, reported by previous workers for larches from different geographical regions--that there is a considerable variation in the increment of larches from different sites within the same general area of distribution. In general, the wider the difference in climate between the localities of origin, the more pronounced are the racial differences. Auer concludes that the species Larix decidua Mill (L. europaea Lam. et D. C.) must be considered a very complex aggregate of varieties, subvarieties, local types and races, very closely adapted to their stations. It is impossible as yet to indicate

the race that will suit a particular site in all respects. The chief conclusion is that so far as possible seed should be collected from the immediate vicinity of the area to be regenerated.

Baldwin (1949a) reported on growth of European larch after 4 years of growth at Fox Forest, New Hampshire. Seed from 47 sources in Europe were planted. Indications are that seed collected at the higher elevations and at the colder localities in the lowlands resulted in slower growing plants than those from medium elevations in central Europe. Seed from Poland and medium elevations in Austria and Czechoslovakia have so far exhibited the most rapid growth. In Wales, Varma (1949) found that the race of European larch, called Darnaway, from Scotland, proved to be the best, and the race from Inn Valley, Austria, the worst. He found the length of branches is a morphological character which distinguishes the race; the angle of branching does not. Height growth is also a racial character and may be used to separate races under similar soil and vegetation conditions. There are significant differences between provenances in respect to straightness of stem and liability to lose the leading shoot.

Of maritime pine, Duff (1928) reviewed the varieties and geographical forms in Europe and South Africa. Perry (1940) recognized four races: (1) Landes (French Atlantic coast), (2) Portuguese (forests of Leiria and Marinha Grande), (3) Corsican, and (4) Esterel (Esterel and Var regions, southern France, or Lucca in northern Italy). Under western Australian conditions the Portuguese strain is faster growing than any others, exhibits particularly good form, and is now being planted almost exclusively. The strain designated as Esterel has not only a very slow rate of growth but also poor form. The Portuguese race is superior to others when planted in South Africa, according to Rycroft and Wicht (1947). Plantings were made in 1934 to 1936 with six races.

Laurie (1936) discussed seed origin and its importance in Indian forestry. He reported (1938) four different types of branching seen in teak plantations and the probability of their being due to hereditary factors. It appears that varieties arising from seed from dry localities may have considerably exaggerated characteristics when raised in damper and more favorable conditions. He emphasized the necessity for ascertaining that the seed comes from a good origin when making teak plantations. Sen Gupta (1941) also discussed the importance of seed origin in teak. For ease of establishment and early development, it seems that seed of local origin is superior to that of distant origin within the natural range of teak, but it is probable that for growth, form, timber quality, branchiness, and crop increment per acre, different origins will show trends independent of their early behavior. Kadambi (1945) reported it has long been observed by forest officers in Mysore that teak seed from the Kabakote (moist) district of Mysore, when used in plantations, produces stunted, relatively low, branchy trees with a relatively large number of insect galls. Trees of this origin are also more susceptible to defoliator attack, shed their leaves earlier, and sprout later than do those of Shimoga (Mysore, dry) origin. Teak has been raised in Trinidad from seed imported both from southern India and Burma; seed from the latter source provides much the better growth under the prevailing conditions (Beard, 1943).

A considerable amount of selection and breeding has been done with poplars in the United States and abroad, because of its value as a pulpwood species. The status of this work has been summarized in an excellent manner by Pauley (1949), including the results of selection. Selection of desirable variants and races has been carried on in Sweden (Lindquist, 1948). In France two races of Populus tremula have been described by Silvy-Leligois (1949). One is a mountain race which grows on well-drained slopes, and the other a plains race which grows on the valley bottom and even in the river. The mountain race is straight and well formed, with large, smooth leaves, and shows early and active self-pruning. The plains race is inclined to be crooked, with flattened crown, small leaves often tomentose on the lower side, and dead branches that often persist for a long time.

A Glossary of Genetic Terms[1/]

Allelomorph--Mendelian characters are inherited in alternative pairs (or series). These alternative forms of a gene, which are located at the same point on each one of a pair of chromosomes, are called allelomorphs. Examples: Albinism (recessive), normal pigmentation (dominant); horns (recessive), hornlessness (dominant). Allel, allelic (adj.)--variants.

Amphimixis--The union of maternal and paternal elements in gametic fertilization. See apomixis.

Apomixis--Reproduction in which the sexual organs, or related structures, take part, but in which there is no fertilization, so that the resulting seed is of vegetative nature. See amphimixis.

Backcross--Cross of a hybrid to one of the parental types.

Biotype--A group of individuals all of one genotype.

Blending inheritance--Inheritance in which dominance of either parental character is lacking. Genetic and biometrical methods have shown that this is due, in many cases at least, to the interaction of several multiple factors independently inherited.

Character (a contraction of characteristic)--A term used, often rather vaguely, to designate any form, function, or feature of an organism. The mendelian characters of genetics represent the end product of development in which a definite gene, or genes, have a decisive effect. The constant and unchanging thing, therfore, is the factor (gene) itself rather than the character, and the unity which Mendel observed lies rather in this underlying factor than in the visible, and perhaps variable character, which it produces.

Chromosomes--Dark-staining bodies visible under the microscope in the nucleus of the cell at the time of cell division. The chromosomes carry the genes, lineally arranged, which control the development of mendelian characters.

Cline--A pattern of genetical variation in which the differences of a character or characters are graded in a definite direction of geographic space.

Clone--A group of organisms composed of individuals propagated vegetatively, not by seeds, from a single original individual.

Cytoplasm--The protoplasm of a cell exclusive of the nucleus.

1/ These terms have been adapted from the glossaries in U. S. Department of Agriculture Yearbook for 1936 and Forest Tree Breeding and Genetics, by Richens; also from the Dictionary of Genetics, by Knight.

Dihybrid--An individual from a cross between parents differing in two genes or differing in two specified genes.

Diploid--Having two chromosome sets only.

Dominant--A character possessed by one of the parents of a hybrid, which is manifested in the hybrid to the apparent exclusion of the contrasted character from the other parent (the recessive). Thus in a cross of green- and yellow-seeded peas the first generation has yellow seeds. Yellow is dominant and green is recessive, being transmitted but not appearing in the presence of the factor for yellow.

Dysgenic--Tending toward racial deterioration, in particular toward a loss of vigor and productiveness.

Ecocline--The graduations of variation produced within a species by its reaction to the different ecological zones in which it occurs.

Ecospecies, ecotype--A distinct race resulting from the selective action of a particular environment. More strictly "ecotype" is "used as an ecological sub-unit to cover the product arising as a result of the genotypical response of an ecospecies to a particular habitat' and "ecospecies" is "the genotype compound narrowed down to the ecological combination limit."

Eugenics--The science which deals with influences that improve inborn or hereditary qualities of a race or breed, especially of the human race.

F_1--The first-generation offspring of a given mating.

F_2--The second filial generation. The first hybrid generation in which Mendelian segregation occurs. Produced by intercrossing or self-fertilizing the F_1. F_3, F_4, etc., denote later generations from a given cross.

Factor--A unit occupying a fixed chromosomal locus and governing, or affecting, the transmission and development of a heritable character; gene.

Factor-pair--Allelomorphs.

Form--A subdivision of a botanical variety distinguished by some minor character. In systematic botany, forms are represented by quadrinomial Latin names.

Gene--The unit of inheritance which is transmitted in the germ cells, and which by interaction, with the genic and cytoplasmic complex and the environment, controls the development of a character. The genes are supposed to be arranged lineally in the chromosomes.

Genetics--The science of heredity, variation, sex determination, and related phenomena.

Genotype--The entire genetic constitution, expressed and latent, of an organism. The term can also be used in dealing with the genetic constitution of an individual with respect to any limited number of genes under examination. A group of organisms all with the same factorial constitution. (See phenotype)

Genotypes, number of--The number of distinct genotypes expected in F_2 is given by calculating 3^n where N is the number of factor-pairs involved. In a backcross, the number of genotypes is 2^n.

Haploid--Having one chromosome set only.

Heritable--Capable of being inherited.

Heterosis--The manifestation in a hybrid of a degree of vigor superior to that exhibited by either of the parents.

Heterozygous--Containing both genes of an allelomorphic pair, or two genes of an allelomorphic series. Heterozygous individuals usually either resemble the individuals homozygous for the dominant character or are intermediate with respect to this character. They transmit the recessive gene to half their offspring.

Homozygous--1. [An organism] formed by like germ cells. 2. An organism is said to be homozygous for a given character when all its germ cells transmit identical genes for this character. This is the most frequently used meaning of the term.

Hybrid--The offspring of two parents unlike one another in one or more heritable characters.

Interspecific selection--Selection which operates to improve the competitive power of one species in relation to other species, as distinct from intraspecific selection, q.v.

Intraspecific selection--Selection which operates as between individuals within a species, as distinct from interspecific selection, q.v.

Mass selection--Selection of a group of superior individuals for breeding purposes. The progeny are not kept separate according to individual female parents.

Mendel's law--Mendel enunciated three basic principles of heredity: (1) Inheritance of character determiners (genes) as allelomorphic units, not as a blend; (2) dominance; (3) independent random segregation of allelomorphs in the formation of gametes and their random recombination at fertilization. As a consequence of these conditions, a given allelomorphic pair of unit characters appears in a certain definite predictable ration (3:1; 1:2:1, 1:1) among the progeny of a given mating.

Mother tree selection--Selection of mother trees without controlling the pollen parent. The progeny are kept separate by individual mother trees.

Multiple factors--Two or more pairs of factors having a similar supplementary, complimentary, or cumulative effect. In a broader sense, any factors working together to produce a single result.

Mutant--An individual which has suddenly acquired a heritable variation not present in the parent form, and, by extension, the offspring of such an individual as "mutant race," "mutant strain."

Mutation--A sudden variation that is later passed on through inheritance, and that results from changes in a gene or genes.

Ortet--The one original plant from which a clone ultimately derives.

Phenotype--The organism as exemplified by its expressed characters, as contrasted with its genetic constitution (the genotype).

Phenotypic--Appertaining to the physical makeup of an organism or group of organisms as distinct from their genetic makeup. The phenotypic effect of any particular gene on an organism is its outward measurable quantitative or qualitative effect on that organism.

Polybrid--A group name for hybrids from crosses between two particular species, varieties, or genera.

Polygenic character--A character whose inheritance is controlled by many genes each having an effect which is small compared with nonheritable variation.

Polyploid--Having more than two sets of chromosome (see diploid and haploid).

Population--A group of individuals among which interbreeding and gene exchange can occur.

Provenance--Place of origin.

Pur line--A strain of organisms that is genetically pure (homozygous) because of continued inbreeding or self-fertilization, or through other means.

Race--A naturally occurring variety.

Ramet--An individual member of a clone.

Recombination--The rearrangement of linked genes due to crossing-over.

Roguing--Elimination of unsatisfactory plants in selection.

Segregation--Separation of the genes of a pair in the formation of germ cells, the two genes going to different gametes. Segregation is manifested in the F_2 (and later hybrid generations) as a separation and distribution to different individuals of the Mendelian characters in which the parents of the F_1 hybrid differed.

Selection -The choice (for perpetuation by reproduction) from a mixed population of the individuals possessing in common a certain character or a certain degree of some character. Two kinds of selection may be distinguished (1) natural selection, in which choice is made automatically by the failure to reproduce (through death or some other cause) of the individuals who are not "fit" to pass the test of the environment (vitality, disease resistance, speed, success in mating, or what not); and (2) artificial selection, in which the choice is made consciously by man, as by a plant or livestock breeder, for characters of value to man

Sport--A mutation; an abrupt deviation from type.

Strain--A group within a variety which constantly differs in one or more genetic factors from the variety proper.

Subspecies-- The subspecies or geographic race is a geographically localized subdivision of the species which differs genetically and taxonomically from other subdivisions of the species.

Topocline--A cline in respect of topographical factors.

Trait--A term often used as a synonym of "character."

Variant--An organism differing slightly from the type.

Variation--In biology, the occurrence of differences among the individuals of the same species or variety.

Variety--A group of strains or a single strain which, by its structural or functional characters, can be differentiated from another group. They are usually represented by trinomial Latin names.

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COMPARATIVE STUMPAGE PRICES for Small Pine Saw Timber and Pulpwood

by

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COMPARATIVE STUMPAGE PRICES FOR SMALL PINE SAW TIMBER AND PULPWOOD

by

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The purpose of this paper describing comparative stumpage prices is to provide a convenient marketing aid for sellers of pine stumpage who wish to know whether it is more profitable to sell their stumpage as saw timber or pulpwood.

In the southern Piedmont, the dominant pine markets are pulpwood and saw timber. Integrated sales of pulpwood and saw timber are not common, and the usual sale is for a single product. Trees below 8 inches d.b.h. (diameter breast high) are seldom cut for lumber, and trees above 14 inches d.b.h., where size and quality generally favor saw-timber markets, are not commonly cut for pulpwood. Between these diameter limits, pine of average quality is commonly bought and sold in lively competition between sawmill operators and pulpwood contractors.

Ignoring quality, the pulpwood stumpage value of a tree or stand is the product of volume in cords and the obtainable price per cord. For the same tree or stand, the saw-timber stumpage value is, similarly, the product of the saw-timber volume and the obtainable price per thousand board feet. If, as frequently occurs, an owner has the choice of selling to either a pulpwood or a saw-timber market, it is to his advantage to know how the obtainable price per cord and per thousand board feet compare. For example, if a sale is contemplated in a stand where the trees to be sold have a ratio of cordwood volume to board-foot volume of 3 cords for each thousand feet of saw timber, it is clear that an equivalent saw-timber stumpage price must be three times the pulpwood price per cord. Thus, when pulpwood is selling for 3 dollars per cord, an equivalent saw-timber bid above 9 dollars would be more attractive.

Comparative prices between these two products are easily obtained by comparing two ratios, one of which is a characteristic of the trees to be sold and the other a market condition. The first is the ratio of cords/MBF; the second is the ratio of going price per MBF to that of pulpwood per cord. When the two ratios are equal, neither product has a financial advantage. This situation is expressed as follows:

$$\frac{\text{Cords}}{\text{MBF}} = \frac{\text{Price per MBF}}{\text{Price per cord}}$$

If the price ratio is greater than the volume ratio, a saw-timber sale is more attractive to the owner, and if the price ratio is less, a pulpwood sale is preferred.

Except within narrow limits of bargaining, forest owners and buyers are not able to alter the bidding price of saw timber or pulpwood. Consequently, the price ratio at the time of sale is fairly stable, and if the owner's choice of market depends upon a financial advantage, he should know something of the volume ratio of the trees to be sold.

The volume ratio (cords/MBF) changes with all the factors which affect either board-foot or cubic-foot volume, including diameter, form, and height of the tree, utilization practice, and method of scaling. One method of obtaining volume ratios is to construct volume tables by diameter and height, showing average cordwood volume to a pulpwood top, and average board-foot volume of the saw-timber portion of the same tree. Height classification may be by total height or by merchantable height in number of pulpwood bolts. Tree form may be included as a variable if greater precision is desired. For purposes of this discussion, and for general use, these variables have been compressed to their average values in a local volume table based on diameter only.

Tables 1 and 2 show merchantable height and volume by d.b.h. classes for average trees of typical loblolly pine stands in the southern Piedmont, on the Hitchiti Experimental Forest. 1/ In each diameter class, merchantable height of saw timber is to a nominal 7-inch top, and merchantable height of pulpwood is to a 4-inch top, inside bark.

Table 1.--Solid and stacked pulpwood volumes of average trees

D.b.h. (inches)	5-1/4-ft. bolts	Solid volume	Stacked volume 1/
	Number	Cubic feet	Standard cords
8	6	7.6	.08
9	7	10.9	.11
10	7	13.9	.15
11	8	18.8	.19
12	9	25.0	.24
13	9	29.7	.29
14	10	37.4	.37

1/ Stacked volume is derived from solid volume and merchantable height by the equation: Stacked volume = .00195(# of bolts) + .00932(solid volume). Taken from "Stacked and Solid Volume of Southeastern Pulpwood," by F. X. Schumacher, Jour. Forestry 44: 579-82, 1946.

1/ Southern Piedmont Research Center of the Southeastern Forest Experiment Station, located near Macon, Ga.

Table 2.--Board-foot contents of average trees by International 1/4-inch, Scribner, and Doyle log rules

D.b.h. (inches)	Merchantable length of tree	Saw-timber volume		
		Int. 1/4-in.	Scribner	Doyle
	Feet	Bd. ft.	Bd. ft.	Bd. ft.
8	14	20	18	12
9	18	30	27	16
10	24	44	39	22
11	28	60	53	30
12	32	82	71	39
13	38	106	91	56
14	42	146	125	83

Ratio of Number of Cords per M Board Feet

The stacked volumes in table 1 and board-foot volumes in table 2 provide a basis for determining the ratio of number of cords per M board feet by d.b.h. classes (table 3).

Table 3.--Ratio of number of cords per M board feet by International 1/4-inch, Scribner, and Doyle log rules

(In cords per M board feet)

D.b.h. (inches)	Int. 1/4-in.	Scribner	Doyle
8	4.0	4.4	6.8
9	3.7	4.1	6.8
10	3.4	3.8	6.8
11	3.2	3.6	6.3
12	2.9	3.4	6.2
13	2.7	3.2	5.2
14	2.5	3.0	4.5

The gross error in estimating board-foot contents by the Doyle rule accounts for the high cords/MBF ratios when using this rule. The International 1/4-inch rule is considered to provide the best estimate of actual lumber tally.

Upon determining the number of cords per thousand board feet by d.b.h. classes and by any log scaling system, the comparative stumpage prices for pulpwood or saw timber for any given volume ratio may be read directly from the chart in figure 1.

Another type of chart which some may wish to make for their particular locality and scaling method is shown in figure 2. This chart applies

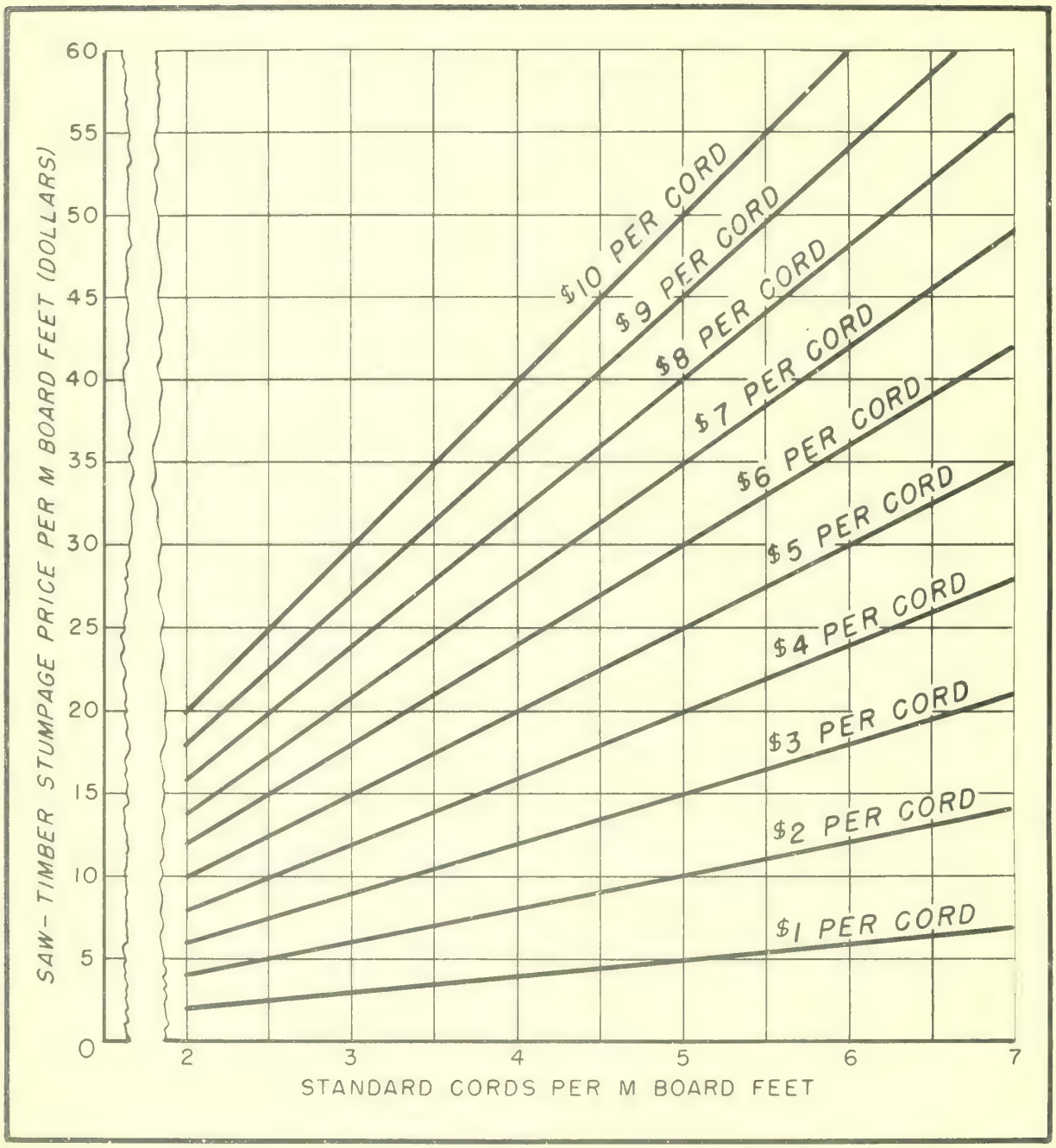

Figure 1.--Comparative stumpage prices for pulpwood and saw timber based on number of standard cords of pulpwood per M board feet of saw timber. Average ratios of cords per M board feet for different tree sizes and log scales can be read from table 3.

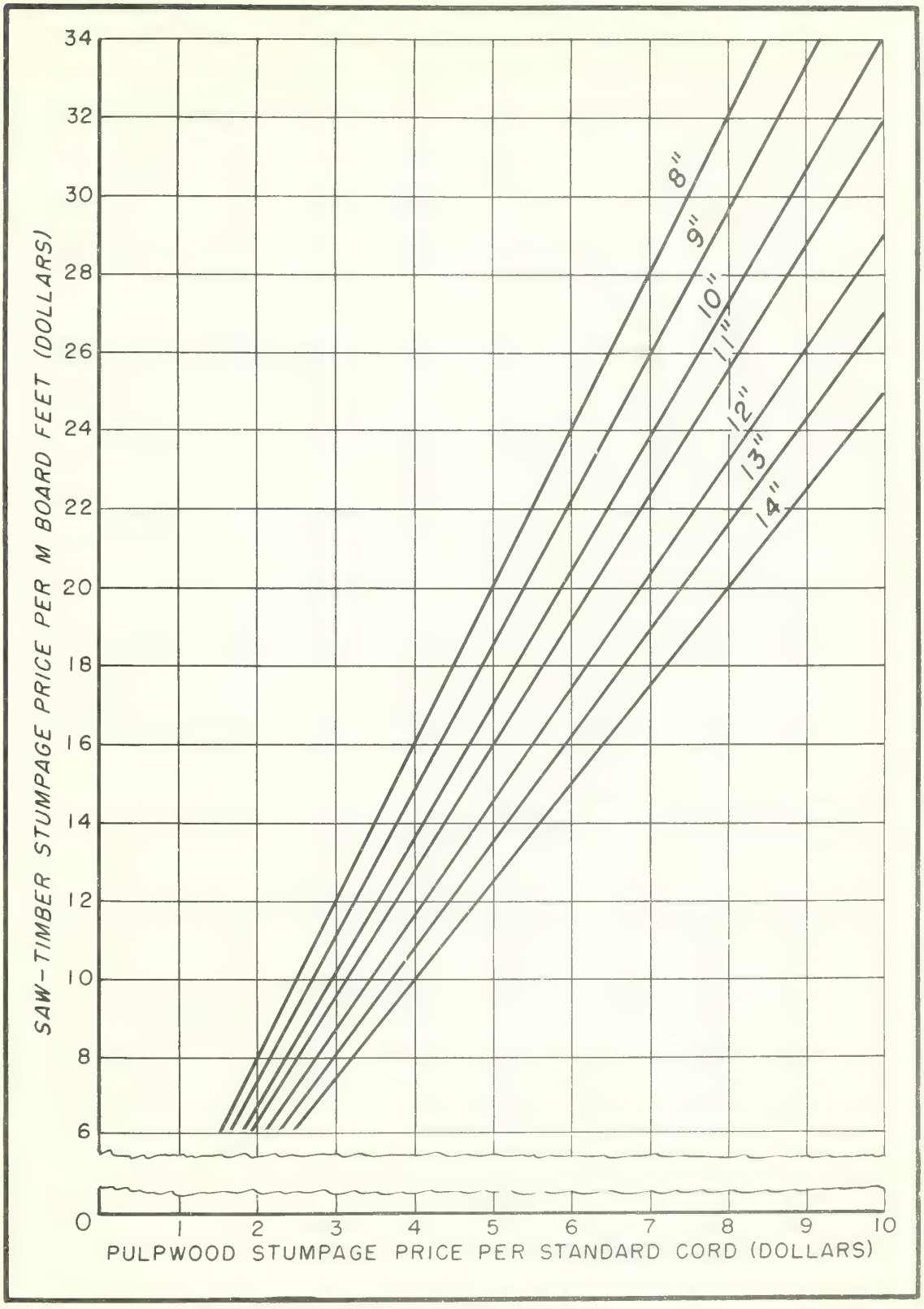

Figure 2.--Comparative stumpage prices for loblolly and shortleaf pine pulpwood and saw timber, International 1/4-inch scale, in the southern Piedmont. This scale most closely approximates a mill tally scale.

to average trees in the southern Piedmont, and is based on the ratios of cords/MBF for the International 1/4-inch scale as given in table 3. Where Scribner or Doyle log rule is more commonly used, a similar chart based on the respective ratios of cords/MBF may be constructed.

Application of Comparative Stumpage Values

Anyone with merchandise to sell ought to know something about it so that he can make a wise trade. Most sellers of stumpage should know at least how many trees by d.b.h. classes he has for sale before he accepts a final bid. In typical even-aged stands, where all the trees marked for cutting are about the same size, a single average diameter is sufficient. In many-sized stands, where the trees marked for cutting have a wide variation, a tally of trees by d.b.h. classes would be more useful.

By using the volume ratios from table 3 in conjunction with figure 1, a seller of stumpage can determine whether he should sell his trees for pulpwood or saw timber.

For example, a tally of trees to be cut in an even-aged stand may indicate an average diameter of 10 inches. From table 3 the cords/MBF ratio by International 1/4-inch scale is 3.4. If the going stumpage price for pulpwood was $3.00 per cord, a comparative saw-timber stumpage would be $10.00 per M board feet International 1/4-inch (see figure 1). If the saw-timber stumpage price offered is more than this, the seller should sell his trees for saw timber; otherwise, he should sell them for pulpwood. A similar procedure would be followed if the saw-timber stumpage price was known and a comparative pulpwood price was desired.

Where the small quantities of cordwood in the tops of saw-timber trees can be marketed for pulpwood, the borderline cases can best be decided in favor of saw timber. In the interest of simplicity, no account was taken of this fact in the determination of comparative stumpage values.

If a cut were to be made in a many-sized stand, there would be a wider range of diameters, and the seller may want to know which trees should go for pulpwood and which for saw timber. Assuming the going stumpage prices are $4.00 per cord and $15.00 per M International 1/4-inch, a cords/MBF ratio, taken from figure 1, is 3.7. Inspection of the International-scale column in table 3 shows that the 3.7 ratio applies to the 9-inch diameter. Thus, a seller would receive the greatest profit by selling trees 10 inches and larger for saw timber and trees 9 inches and less for pulpwood. If the bulk of trees were under 10 inches, he would probably have to sell the entire cut as pulpwood, and vice versa if most of the trees were over 10 inches. By using a chart similar to figure 2, this diameter breaking-point may be determined directly for International 1/4-inch scale.

There is a more limited market for poles and piling or veneer stock, and if the seller feels that some of his trees may qualify, he should contact buyers, learn their specifications, and then look over his timber again. If there is a sufficient number of trees that meet the specifications, it will nearly always be most profitable to sell these trees in such markets.

In any sale, regardless of product being sold, there are factors other than price which should be taken into consideration. The opportunity to sell readily in the several markets may be lacking. The integrity of the buyer or operator, the confidence the seller has that the operator will cut only marked trees with little damage to the remaining trees, and the method and promptness of payment, are all points which may favor one buyer in spite of a small difference in stumpage price.

Application of Ratios Outside the Southern Piedmont

The data apply particularly to the shortleaf-loblolly pine stands of the southern Piedmont, but may be applied in other areas where tree taper, top d.i.b. (diameter inside bark), utilization, and log and bolt lengths cut are similar. Anyone using these data should satisfy himself that the general run of trees in his area have ratios of cords/MBF similar to those shown in table 3. If utilizable volumes by d.b.h. classes for pulpwood and saw timber can be determined with reasonable accuracy and are found to differ from those given, a new set of ratios based on local data can be prepared quite easily. One may then use the chart in figure 1 to determine comparative stumpage prices for pulpwood and saw timber in his locality. If the local ratios cannot be determined, or if only rough approximations can be made, then the comparative stumpage prices based on the ratios in table 3 should not be used indiscriminately, but be considered only as rough guides.

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Directory of FOREST GENETIC ACTIVITIES in the South

by

Keith W. Dorman

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina
E. L. Demmon,
Director

U. S. Department of Agriculture - Forest Service

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FOREWORD

This publication was prepared in cooperation with the Committee on Southern Forest Tree Improvement. It is the purpose of this committee to: (1) advise and assist those interested in the improvement of southern forest trees in arranging and conducting research and development programs; (2) provide a clearing house for information on forest tree improvement; (3) provide for or assist in coordination in the conduct of a South-wide program of tree improvement research and development; and (4) foster and encourage the advancement of knowledge of southern tree genetics. The present publication lists, characterizes, and locates work now in progress in the South; it was compiled from information given by organizations working in the field.

Subcommittee on Tree Selection and Breeding

D. A. Anderson--Texas Forest Service
Woolford B. Baker--Emory University
Spencer Chase--Tennessee Valley Authority
C. C. Doak--Agricultural and Mechanical College of Texas
Ellwood S. Harrar--Duke University
Paul H. Harvey--North Carolina State College
C. M. Kaufman--University of Florida
Scott S. Pauley--Maria Moors Cabot Foundation for Botanical Research
Maxon Y. Pillow--Forest Products Laboratory
F. I. Righter--California Forest and Range Experiment Station
Ernst J. Schreiner--Northeastern Forest Experiment Station
Brataslav Zak--Bureau of Plant Industry, Soils and Agricultural Engineering
Bruce Zobel--Texas Forest Service
Keith W. Dorman--Southeastern Forest Experiment Station (Chairman)

Previous publications and reports prepared in cooperation with the Committee on Southern Forest Tree Improvement are:

1. Report of the first southern conference on forest tree improvement. Atlanta, Ga., January 9-10, 1951. Mimeographed. U. S. Forest Service, Atlanta, Ga.

2. Proposal for a cooperative study of geographic sources of southern pine seed. Subcommittee on Geographic Source of Seed, Philip C. Wakeley, Chairman. Mimeographed. Southern Forest Experiment Station, New Orleans, La. Oct. 25, 1951.

3. Standardized working plan for local tests of seed source. Subcommittee on Geographic Source of Seed, Philip C. Wakeley, Chairman. Mimeographed. Southern Forest Experiment Station, New Orleans, La. Oct. 25, 1951.

4. Hereditary variation as the basis for selecting superior forest trees. Keith W. Dorman, Chairman, Subcommittee on Tree Selection and Breeding. Southeastern Forest Experiment Station, Station Paper No. 15. March 1952.

DIRECTORY OF FOREST GENETICS ACTIVITIES IN THE SOUTH

by

Keith W. Dorman[1/]
Forester, Southeastern Forest Experiment Station
Asheville, N. C.

To many people, forest genetics means controlled breeding. This is only one phase of the work. There must be a program of plant introduction to test foreign species for adaptability to local conditions. Also, races, strains and varieties of each local species must be studied before the best breeding material is found. There are problems in techniques to be solved such as those in testing progeny of selected trees or the hybrids. Also, methods of propagating by vegetative means are needed for trees used as breeding stock or those of superior varieties. These are but a few of the phases of forest genetics work, but they and many others are necessary before attaining the objective--better forest trees.

Formal research in forest genetics is relatively new in the South. Some studies have been made of racial variation in important species, and foreign species have been introduced on a small scale. Also, some of the hybrids produced by the Institute of Forest Genetics are being tested. However, selection and controlled breeding have been started only recently. The lists of studies on the following pages are impressive, and indicate wide and active interest in the improvement of forest trees. But much additional research will have to be undertaken if we are to make the most of the existing opportunities for genetic improvement of southern forest trees.

1/ Chairman, Subcommittee on Tree Selection and Hybridization of the Committee on Southern Forest Tree Improvement.

PLANT-INTRODUCTION STATIONS, ARBORETUMS, AND BOTANICAL GARDENS

Collection of tree species, varieties, and forms in as wide a field as possible is one of the first steps in the development of better forest trees. This is the raw material with which the tree breeder works to create new types or from which he selects those better suited for particular purposes. Arboretums and botanical gardens are the storehouses for breeding material and they are of great importance to the geneticist. Plant introduction workers stock the storehouses and provide a source of raw material that is greatly beyond the means of the average tree breeder. Arboretums and botanical gardens in the South are neither well developed nor well distributed geographically to meet the needs of a broad tree improvement program. Additional stations are needed in the great timber producing regions of the coastal plain and upland areas from the Carolinas to Louisiana. The following list gives arboretums, botanical gardens, and plant introduction stations now established in the South.

Coker Arboretum, Chapel Hill, N. C.

Blandy Experimental Farm Arboretum, Boyce, Va.
Established 1927. 100 acres
Chief function: experimental and research, educational laboratory for graduate students.
Featuring: evergreens, woody trees, and shrubs, conifers in general, Pinus, Berberis, Phlox, Buddleia, and Quercus.

Fairchild Tropical Garden, Coconut Grove, Fla.
Established 1938. 83 acres.
Chief function: to grow all the plant material, both native and exotic, which will thrive in this area.
Featuring: palms and other tropical trees, vines and shrubs adaptable to south Florida.

McIlhenny Arboretum, Avery Island, La.
Established 1900. 300 acres
Chief function: park and bird sanctuary.
Featuring: evergreens, woody trees, and shrubs.

Tennessee Valley Authority, Norris, Tenn.
Established 1936. 100 acres
Chief function: research.

Texas Forest Service, College Station, Texas
Established 1952. 50 acres
Chief function: research
Featuring: Mexican and southwestern pines.

U. S. Dept. of Agriculture Plant Introduction Garden, Chapman Field, Perrine, F

U. S. Dept. of Agriculture Plant Introduction Station, Griffin, Ga.

University of Florida Subtropical Experiment Station, Homestead, Fla
Established 1930. 170 acres.
Chief function: research.

PLANTINGS OF INTRODUCED SPECIES OF FOREST TREES[2/]

The plant breeder must in most instances select breeding stock from among a large number of species. He needs accurate data for tree growth under different climatic and soil conditions, information on resistance or susceptibility to fungi and insects common to the area, and information on tree quality for lumber or other products. Another important consideration is that species or races and varieties of species with wide geographical distribution may be well suited for planting in certain areas and perform better than local species. Only by test plantings can the good prospects be sorted out from the poor ones. Planting of foreign species has been undertaken on a small scale in the Appalachians mountains, southern Florida, and Texas, but little has been done in the Coastal Plain, Piedmont, Ozark mountains, and other areas of the South.

Bent Creek Experimental Forest, Asheville, N. C.
Thuja occidentalis. New York. 1926
Acer saccharum. New York. 1926
Pinus resinosa. Vermont, Michigan, Minnesota. 1926
P. monticola. 1927
P. contorta. 1927
P. densiflora. Japan. 1928
P. nigra var. poiretiana. Indiana. 1928
P. sylvestris. Belgium. 1926
P. koraiensis. Korea. 1929
P. radiata. France. 1929
P. sabiniana. California. 1930
P. rigida var. serotina. North Carolina. 1920
P. attenuata. California. 1930
P. pungens. North Carolina. 1930
P. contorta var. murrayana. California. 1930
P. taeda. North Carolina. 1930
P. caribaea. Louisiana. 1927

2/ The tree names are listed as reported by various agencies and may not follow the same system of nomenclature. However, the spelling has been changed in some instances to conform with that given in Standardized Plant Names, 2nd edition.

Pinus palustris. North Carolina. 1929
Libocedrus decurrens. Washington. 1927
Picea sitchensis. 1927
P. glauca. 1927
Abies concolor. California. 1930. Colorado. 1926
Chamaecyparis thyoides. Virginia. 1927
Chamaecyparis lawsoniana. California. 1930
Larix leptolepis. Japan. 1928
L. occidentalis. 1930
Cornus mas. France. 1929
C. sanguinea. France. 1929
Ginkgo biloba. Washington, D. C. 1929
Albizzia julibrissin. 1929
Gleditsia triacanthos. 1929
Pseudotsuga taxifolia. 1929
Cercis canadensis. 1929
Castanea mollissima. 1929
C. crenata. 1929
C. sanguinni. 1929
C. dentata. 1929
Cupressus macnabiana. California. 1930
Fraxinus oregona. Oregon. 1930
Metasequoia glyptostroboides. China. 1950

Coker Arboretum, University of North Carolina, Chapel Hill, N. C.

Acer palmatum
Aesculus hippocastanum
Ailanthus altissima
Albizzia julibrissin
A. lebbek (= A. kalkora)
Aralia chinensis
Broussonetia papyrifera
Cephalotaxus drupacea
Clerodendron trichotomum
Cryptomeria japonica
Cunninghamia sinensis
Fontanesia fortunei
Ginkgo biloba
Juglans sieboldiana
Juniperus communis var. hibernica
Koelreuteria paniculata
Lagerstroemia indica
Libocedrus decurrens
Magnolia denudata
M. soulangeana
Osmanthus aquifolium
O. fragrans
Paulownia tomentosa
Picea orientalis
Pinus australis
Pistacia chinensis
Podocarpus macrophyllus
Prunus sieboldi
Quercus glauca
Sterculia platanifolia
Styrax japonica
Thuja orientalis
Tilia europaea
Zizyphus jujuba
Z. jujuba var. lang.
Cercis chinensis

Florida Board of Forestry, Tallahassee, Fla.
Many tropical hardwood and softwood species planted at Highland Hammock State Park, Sebring, Fla.

Forestry Department, Alabama Polytechnic Institute, Auburn, Ala.
Cupressus arizonica. 1949

Georgia Agricultural Experiment Station, Experiment, Ga.

Pinus pseudostrobus. 1950
P. douglasiana
P. cembroides
P. strobus var. chiapensis
P. ayacahuite
P. nelsoni
P. oocarpa
P. ayacahuite var. brachyptera. 1949
P. micheasana var. cornuta
P. hartwegi
P. engelmanni
Taxodium mucronatum

Ida Cason Callaway Foundation, Hamilton, Ga.

Abies religiosa. Mexico. 1951
Pinus ayacahuite. Mexico. 1951
P. pinaster. Portugal. 1951
P. strobus. North Carolina. 1951
P. hartwegi. Mexico. 1951
P. cembroides. Mexico. 1951
P. strobus var. chiapensis Mexico. 1951
P. lambertiana. Arnold Arboretum. 1951
P. pseudostrobus. Mexico. 1951
P. bungeana Arnold Arboretum. 1951
P. nelsoni. Mexico. 1951
Crataegus mexicana. Mexico. 1951
Taxodium mucronatum. Mexico. 1951
Cupressus (standleyi). Mexico. 1951
Platanus mexicana. Mexico. 1951
Chilopsis linearis. Arizona. 1951
Cedrus libani. Arnold Arboretum. 1951
Widdringtonia dracomontana. South Africa. 1951
W. cuppressoides. South Africa. 1951
W. schwarzi. South Africa. 1951

North Carolina Dept. of Conservation and Development, Division of Forestry, Raleigh, N. C.

Pinus pinaster. Fort Macon, N. C. 1929
P. pinaster. Nags Head, N. C. 1948
Asiatic chestnut, Nanking strain. Holmes Nursery, Penrose, N.C. 1945

Oklahoma Agricultural Experiment Station and Oklahoma State Division of Forestry, Oklahoma City, Okla.

Pinus thunbergi. Central and western Oklahoma. 1940 to 1950
P. densiflora. " " " " " " "
P. massoniana " " " " " " "
Russian mulberry. Woodward, Okla.
Chinese elm " "
Parvifolia elm " "
(many others)

Pisgah National Forest, Asheville, N. C.

Picea abies. 1925
P. glauca. 1924
P. engelmanni. 1926
P. sitchensis. Washington. 1931
Pinus densiflora. 1924
P. contorta. 1926
P. thunbergi. 1923
P. resinosa. Minnesota. 1926
P. sylvestris. Belgium. 1926
P. monticola. Idaho. 1923
Thuja occidentalis. Ontario, Canada. 1926
Pseudotsuga taxifolia. Montana. 1923
Larix leptolepis. Japan. 1924
L. decidua. 1924
Abies concolor. 1927
Thuja plicata. British Columbia. 1930
Abies alba. 1924

South Carolina National Forest, Columbia, S. C.

Sequoia, sp. Enoree Ranger District. 1900
Cryptomeria, sp. Enoree Ranger District.

Tennessee Valley Authority, Norris, Tenn.

Carya spp.
Castanea mollissima
C. crenata
C. henryi
Diospyros kaki
Morus spp.
Juglans nigra
J. regia
J. sieboldiana
J. cincerea
(Juglans hybrids)
Populus alba
P. tremuloides
(Populus hybrids)
Quercus acutissima
Q. leucophylla
Robinia pseudoacacia (straight-stem selections)

Texas Forest Service, College Station, Texas

Pinus pumila
P. griffithi
P. chihuahuana
P. douglasiana
P. pinea
P. cembroides
P ayacahuite var. veitchi
P. leucodermis
P. pseudostrobus
P. bungeana
P. patula
P. nelsoni
P. hartwegi
P. formosana
Pinus oocarpa
P. rudis
P. lambertiana
P. strobus var. chiapensis
P. parviflora
P. michoacana var. cornutu
P. yunnanensis
P. tabulaeformis
P. holfordiana x P. parviflora
P. thunbergi
P. flexilis var. reflexa
P. pinaster
P. nigra var. cebennensis
P. armandi

Pinus halepensis	Pinus hunnewelli (P. strobus x P. parviflora)
P. engelmanni	P ayacahuite var. brachyptera
P. gerardiana	P. modoomata (P. densiflora x P. thunbergi)
P. massoniana	P. pseudostrobus var. estevezi
P. arizonica	P. coult ri x P. jeffreyi (natural hybrid)
P. coulteri	P. rigid x P. taeda
P. jeffreyi	P. atten radiata (P. attenuata x P. radiata)
P. excelsa	P. resinosa
P. contorta	P. longifolia
P. attenuata	Eucalyptus spp.
P. insularis	Acacia spp.
P. ponderosa	

West Virginia Pulp and Paper Co., Westvaco Expt. Forest, Georgetown, S.C.:
Araucaria angustifolia
Cupressus arizonica
P nus rad ata. 1951
P. radiat x P. attenuata. Hybrid. California
Me asequoia glyptostroboides. China. 1950
Populus hybrids
S q oia sp.

STUDIES OF RACIAL VARIATION

It has been established that races varying in vigor, disease resistance, and cold resistance occur in some species of southern pines. This poses a problem to those responsible for collecting the seed from which 2 0 million or more seedlings are grown each year. Where shall seed be collected? If there is a short seed crop in one State, can supplementary seed be obtained from others? To provide answers to these questions for immediate use, and also to provide data for future selective breeding work is the purpose of current studies of the variation within species of southern pines and hardwoods.

College of Agriculture, Univ. of Arkansas, Fayetteville, Ark.:
Pinus taeda, P. echinata, and Juniperus virginiana from 4 locations within the State. Established 1952.

Committee on Southern Forest Tree Improvement, Subcommittee on Geographic Source of Seed:
Arranged with 25 agencies, in fall of 1951, the collection of Pinus palustris from 11 sources in 8 states; P. caribaea from 6 sources in 5 states; P. taeda from 15 sources in 10 states; and P. echinata from 15 sources in 12 states. Outplanting at approximately 60 locations in 16 states is planned for 1952-1953.

Division of Forest Pathology, Bureau of Plant Industry, Soils, and Agricultural Engineering, U.S.D.A.:

Pinus echinata from all Southern states throughout range. To be planted in 1952. (Athens, Ga.)

Pinus caribaea from North Florida, South Florida, and Mississippi. Planted in 1949. (Harrison Expt. Forest, Saucier, Miss.)

Pinus taeda, 6 sources, North Carolina to Louisiana. Planted in 1951. (W. W. Ashe Nursery, Brooklyn, Miss.)

Pinus caribaea, 6 sources, South Carolina to Louisiana. Planted in 1948.

P. caribaea, South Florida, North Florida, Mississippi, and Cuba. Planted in 1949. (Chickasawhay Ranger District, Miss. Nat'l Forest; State College, Miss.; and Santee Expt. Forest, Charleston, S. C.)

Forestry Department, Alabama Polytechnic Institute, Auburn, Ala.:

Adaptation of Florida slash pine. Established in 1935.

Northeastern Forest Experiment Station, Upper Darby, Pa.:

Fraxinus americana and F. pennsylvanica of southern and northern sources. Planted in 1940. (Harvard Forest, Petersham, Mass.) New racial plantings made in 1951 and 1952 at Williamstown, Mass., and Beltsville, Md.

Acer rubrum of different geographic sources.

Pennsylvania Department of Forests and Waters, Harrisburg, Pa.:

Pinus echinata, Tennessee, Arkansas, Texas, Louisiana, Mississippi, and South Carolina. Planted in 1935.

Southeastern Forest Experiment Station, Asheville, N. C.:

Pinus taeda, 9 sources. Planted in 1950. (Calhoun Expt. Forest, Union, S. C., in cooperation with TVA)

Pinus taeda and P. echinata, 5 sources of each. Planted in 1945. (Lee Experimental Forest, Buckingham, Va.)

Pinus resinosa from Vermont, Michigan, and Minnesota. Planted in 1926. (Bent Creek Expt. Forest, Asheville, N. C.)

Pinus glabra, Mississippi and local source. Planted in 1952. (Santee Experimental Forest, Charleston, S. C.)

Southern Forest Experiment Station, New Orleans, La.:

Pinus taeda from Georgia, Arkansas, Texas, and Louisiana. Planted in 1927. (Bogalusa, La.)

Pinus taeda, 12 sources; P. caribaea, 7 sources; P. echinata, 14 sources. Planted in 1937. (Jasper, Texas, and Athens, Ga.)

Pinus palustris seed from good and poor sites collected in 1947 and 1948; stock of all four sources outplanted on both National Forests in 1948-49 and 1949-50. (Talladega Nat'l Forest, Ala., and DeSoto Nat'l Forest, Miss.)

Pinus taeda from 9 sources. 1950. In cooperation with TVA. (Birmingham, Ala., Harrison, Ark., and Oxford, Miss.)

Tennessee Valley Authority, Norris, Tenn.:

Castanea, timber type species planted; selected and hybrid blight resistar strains. Established 1946-1951. (U.S.D.A. in cooperation with TVA, Norri Tenn., and at 10 other locations.)

Juglans nigra, 10 sources based on kernel content. Established 1940. (Norris, Tenn.)

Juniperus virginiana, 12 seed sources; established 1950. (Planted at 3 locations in Tenn.)
Rhammus purshiana, 1 source; established 1948. (Norris, Tenn.)
Robinia pseudoacacia, 3 sources; established 1938-39. (Planted at 170 locations in Tennessee Valley.)
Pinus, many geographic sources. Proposed planting locations: (Cullman Co., Ala., and Morgan Co., Tenn. Southern Forest Experiment Station in cooperation with TVA.)

Texas Forest Service, College Station. Texas:
Pinus taeda from 10 sources within the State and 2 from Louisiana were planted in Post Oak region in 1952.

University of Virginia, Blandy Experimental Farm, Boyce, Va.:
Fraxinus and Acer of several races. Also, Quercus species and known and putative hybrids.

PROJECTS IN SELECTION AND HYBRIDIZATION

Selection of genetically superior individual trees or superior races within a species permits use of the best combination of traits that occur in nature. Controlled breeding of selected individuals combines traits in still better combinations--combinations that would perhaps never occur under natural conditions. This permits further selection and breeding. Also, crosses of certain species may have hybrid vigor, with growth superior to both parents. Selective breeding or aimed breeding should create trees of higher value for all-around forest planting, or trees of greater utility for certain products. These benefits may be achieved through greater vigor, improved tree form, better wood, reduced loss from climatic factors, and smaller losses from diseases or insects. To obtain these benefits i the objective of tree breeders in the South. Most of the projects are using the direct approach by applying principles used successfully with other crop plants. There is great need for studies to develop principles based on the fundamental life processes of local species of pines and hardwoods.

Ida Cason Callaway Foundation, Hamilton, Ga.:
Pinus caribaea, P. palustris, P. echinata, and P. taeda - Large-scale selection of superior phenotypes and one-parent progeny tests with 4 major species of pine. Limited intra- and interspecific hybridization of selected trees. Observation block of P. echinata x P. taeda hybrid established in the spring of 1951.

Division of Forest Pathology, Bureau of Plant Industry, Soils and Agricultural Engineering, U.S.D.A.:
A project has been started in selection and propagation of Pinus echinata resistant to littleleaf disease. (Athens, Ga.)

Selection, hybridization, and vegetative propagation of Albizzia julibrissens resistent to mimosa wilt. (Asheville, N. C.)
Pinus caribaea from Cuba, British Honduras, South Florida, and other points within the natural range are tested for racial variation in resistance to fusiform rust. (Harrison Expt. Forest, Saucier, Miss.)
Open-pollinated seed was collected from disease-free Pinus caribaea as well as from diseased parents in areas of high rust incidence to test for disease resistance in one-parent progeny. Seedlings were planted in 1946 and 1947. A similar test with both P. caribaea and P. taeda seed from Mississippi and Georgia was established in 1947. (W. W. Ashe Nursery, Brooklyn, Miss.)
Selection of disease-free Pinus palustris from unsprayed nursery beds will be made in fall of 1951 in a test for resistance to brown spot needle blight. (W. W. Ashe Nursery, Brooklyn, Miss.)

Forestry Department, Ala. Polytechnic Institute, Auburn, Ala.:
Test of several Pinus taeda x P. echinata crosses of different geographic sources in comparison with parent species. Seed was supplied by the Institute of Forest Genetics.

Georgia Experiment Station, Experiment, Ga.:
One-parent progeny tests of selected southern pines and hybridization of superior trees.

Mississippi Agricultural Experiment Station, College Station, Miss.:
Pinus taeda x P. echinata backcrossed to each of parent species to compare survival, growth rate, and form of hybrid with each species.

Northeastern Forest Experiment Station, Upper Darby, Pa.:
Many interspecific hybridizations within recent years in Fraxinus, Acer, Liriodendron, and Quercus. Also, in Pinus, in the series Strobi, Lariciones, and Insignes.
Pinus rigida x P. taeda and P. echinata x P. rigida hybrids were planted at the Eastern Shore Expt. Forest in Maryland and at the Lebanon State Forest in New Jersey in 1945, being grown from seed produced at the Institute of Forest Genetics.

Southeastern Forest Experiment Station, Asheville, N. C.:
Selection, intra- and inter-specific hybridization, and propagation of Pinus caribaea and P. palustris selected on the basis of superior oleoresin production. Two plantations have been established (1946 and 1950) of species hybrids, and intra-crosses among high, average, and low, gum-yielding P. caribaea. (Olustee Expt. Forest, Lake City, Fla.)
A plantation of Pinus echinata x P. taeda hybrid and seed of same species from various sources was established in 1951. Seed of hybrid stock was provided by the Institute of Forest Genetics. (Hitchiti Expt. Forest, Macon, Ga.)
A test plantation with Pinus monticola x P. strobus and P. rigida x P. taeda was established in 1951. Seed was provided by the Institute of Forest Genetics. (Bent Creek Expt. Forest, Asheville, N. C.)
Seedlings of Pinus rigida x P. taeda hybrid and P. taeda from several sources were planted in 1945. (Lee Expt. Forest, Buckingham, Va.)

Southern Forest Experiment Station, New Orleans, La.:

Planting of a hybrid from controlled pollination in 1929 of Pinus palustris x P. caribaea and a cross in 1931 of P. sondereggeri x P. palustris. Single tree of each cross. (Bogalusa La.)

Limited inter pecific hybridization of southern pines in 1951 and 1952. (Alexandria, La., Branch Station)

Outplantings of hybrids in 1948-49 of Pinus taeda x P. echinata crosses and back-crosses. Seed was from the Institute of Forest Genetics. (Branch Station at Birmingham, Ala., the Ozark at Harrison, Ark., and Tallahatchie at Oxford, Miss.)

Limited interspecific hybridization of southern pines in 1951. (Gulfcoast Branch Station, Gulfport, Miss.)

Outplanting in 1952 of progenies from wind pollination of 7 individuals of Pinus sondereggeri and of one presumed natural P. palustrix x P. caribaea cross. (Many, La. In cooperation with A. J. Hodges Industries, Inc., and Agricultural Experiment Station and School of Forestry, Louisiana State University.)

Tennessee Valley Authority, Norris, Tenn.:

Castanea mollissima, Carya illinoensis, Carya ovata, and Carya hybrids, Corylus americana, Corylus avellana, and Corylus hybrids - Objective: To test the performance of superior selections in the Tennessee Valley. Test plantings have been established at numerous locations to compare variety performance under varying conditions. Project in cooperation with Alabama, Georgia, Kentucky, Tennessee and Virginia Agricultural Experiment Stations.

Pinus taeda, P. echinata, P strobus - Selection of genetically superior seedlings found in TVA forest tree nurseries. Growth of these "superseedlings' compared with average seedlings.

Acer, Betula, Juglans, Liriodendron species - Methods of inducing figured wood. Seedlings of these four species were given several abnormal treatments as a means of inducing formation of figured wood.

Texas Forest Service, College Station, Texas:

Pinus taeda, P. palustris, P. echinata, P. caribaea - Selection of superior phenotypes on the basis of the best silvical and wood characters possible with special emphasis on those characters known, or strongly suspected of being, strictly controlled genetically. Tests with open pollinated progeny of selected trees and later with vegetatively propagated material. Hybridization of selected trees and tests of new equipment for controlled breeding.

University of Arkansas Experiment Station, Hope, Ark.:

Pinus taeda, P. echinata - Comparison of progeny from superior and average parents.

West Virginia Pulp and Paper Co., Westvaco Expt. Forest, Georgetown, S.C.:

Pinus taeda - Trees on two 5-acre seed orchards were selected as mother trees to provide seed for local planting. Forty-four trees 10-20 years have been selected and treatments to stimulate seed production have been applied. One-parent progeny tests have been initiated.

STUDIES IN VEGETATIVE PROPAGATION

Vegetative propagation as opposed to sexual propagation permits endless multiplication of superior plants with identical genetic constitution. Foresters may wish to propagate certain valuable trees, just as horticulturists do with fruit and nut trees. For immediate use tree breeders would like to establish plantations of grafted stock or rooted cuttings to be used in controlled breeding and, in some instances, to produce seed of superior strains in volume. Although some species have been propagated successfully by graftage or cuttage, refinement of techniques is needed to increase the percentage of success and to make the field work easier. Cuttings of chestnut, for instance, have never been successfully rooted. Thousands of slash pine cuttings were treated before the first one was successfully rooted a few years ago.

Division of Forest Pathology, Bureau of Plant Industry, Soils and Agricultural Engineering, U.S.D.A.:
Pinus echinata, methods of grafting. (Athens, Ga.)
Albizzia julibrissens, methods of vegetative propagation. (Asheville,N.C.

Forestry Department, Alabama Polytechnic Institute, Auburn, Ala.:
Cupressus arizonica, grafting and rooting of cuttings.

Southeastern Forest Experiment Station, Asheville, N. C.:
Liquidambar styraciflua, rooting of cuttings. (Charleston, S. C.)
Pinus caribaea and P. palustris, grafting. (Lake City, Fla.)

Tennessee Valley Authority, Norris, Tenn.:
Acer, Betula, Carya, Castanea, Corylus, Diospyros, Gleditsia, Liriodendron, Morus, Robinia, Populus, budding, grafting, root and stem cuttings.

Texas Forest Service, College Station, Texas:
Grafting many introduced species and hybrids on local species stock.

West Virginia Pulp and Paper Co., Westvaco Expt. Forest, Georgetown, S. C.:
Mestasequoia glyplostroboides, rooting of cuttings.

STUDIES IN CYTOLOGY AND METHODS OF INDUCING MUTATIONS

A knowledge of chromosome number in all important tree species and varieties is essential to the plant breeder. Also, he should have accurate data for chromosome pairing if hybrids are to be accurately evaluated, because incomplete pairing may cause sterility. Cytological work is essential in the

study of mutations whether they occur naturally or are artificially induced. Changes in the chromosomes through mutation may produce radically different plants that are essentially new specie . Some commercially important fruit trees such as certain grapefruit varie ties are mutants. The characteristics of mutant f rest trees, especially southern species, are practically unknown, although selection of these unusua trees may be quite profitable.

Georgia Experiment Station, Experiment, Ga.:
Pinus taeda - Cooperative tests with Harvard University of characteristics of irradiated seed.

Northeastern Forest Experiment Station, Upper Darby, Pa.:
Fraxinus americana - Observation plots of natural occurring polyploids obtained in studies of racial variation.

Southeaster Forest Experiment Station, Asheville, N. C.:
Pinus taeda, P. clausa, P. echinata, Liquidambar styracfula - Cooperative tests with Harvard University of characteristics of irradiated seed

University of Virginia, Blandy Expt. Farm, Boyce, Va.:
Chromosome number and phylogeny in conifers.

STUDIES IN STIMULATING SEED PRODUCTION

Selectively breeding several generations of forest trees requires a long time unless they reach sexual maturity at a very early age. Therefore, any techniques to bring about flowering in very young trees is of great practical use to the tree breeder. And, it is important that a large number of flowers be produced. Techniques for stimulating production of seed would have widespread application in seed-orchard management. Grafting twigs of mature trees onto seedlings or grafting twigs of juvenile hybrids to branches of mature trees has increased seed production in certain pine species. Also, root pruning of seedlings, strangulation, partial girdling, and the application of plant nutrients have been successful. Similar or improved techniques are needed for southern forest tree species.

Division of Forestry, North Carolina Department of Conservation and Development, Raleigh, N. C.:
Pinus taeda - Improvement cuts in 50-year-old stand to stimulate seed production.

Southeastern Forest Experiment Station, Asheville, N. C.:
Pinus taeda - Studies in effect of release from the side; two levels of fertilization, and partial girdling on volume and quality of seed. Franklin, Va.

Southern Forest Experiment Station, New Orleans, La.:

Pinus palustris, tests to increase seed production. Brewton, Ala., Branch Station.

Pinus taeda, tests of thinning, strangulation, and ringing to increase seed production. Crossett, Ark., Branch Station.

Pinus palustris, tests of fertilizing and of banding branches to increase seed production. Gulfcoast Branch Station on Gulfport, Miss.

West Virginia Pulp and Paper Co., Westvaco Experimental Forest, Georgetown, S. C.:

Pinus taeda, release and isolation of 1 to 20-year-old trees. Tests of topping and banding to stimulate seed production.

ORGANIZATIONS CONDUCTING WORK IN TREE IMPROVEMENT

The opportunity for increasing yields of forest products through use of more vigorous species and improved strains, races, or hybrids of local species in planting programs has already stimulated considerable interest in forest genetics on the part of industries and public agencies. And it is only beginning. There is also a growing appreciation of the need for maintaining good genetic quality in natural stands through the use of sound timber-cutting practices. Studies in forest genetics will influence and be influenced by studies of forest soils, silviculture, forest management and utilization. As the following list indicates, work on the genetic improvement of southern forest trees is now under way by private industries, a private foundation, state forest services, forestry schools, agricultural experiment stations, regional forest experiment stations, and several other federal agencies. The projects are designed to meet the needs of these widely varied interests.

A. J. Hodges Industries, Inc., Shreveport, La.:

1. Has entered into a formal contract with Agricultural Experiment Station and School of Forestry, Louisiana State University, to conduct research in forest genetics on fenced tract of cut-over longleaf pine land at Many, La.; is reserving 100 acres on tract for Southern Forest Experiment Station's breeding stock and progeny tests.

Arkansas Resources and Development Commission, Division of Forestry and Parks, Little Rock, Arkansas, and Univ. of Arkansas, Fayetteville, Ark.

1. Studies of racial variation in Pinus taeda, P. echinata, and Juniperus virginia.
2. Comparison in growth of trees from Pinus taeda and P. echinata seed collected from plus trees and from average trees.

Department of Forestry, Oklahoma Agricultural Expt. Sta., and Oklahoma State Division of Forestry, Oklahoma City, Okla.:

1. Adaptation tests of Pinus thunbergii, P. densiflora, P. massoniana, and many other species.

Division of Forest Pathology, Bureau of Plant Industry, Soils and Agricultural Engineering, U.S.D.A.:

1. Studies of racial variation in Pinus echinata in resistance to littleleaf disease, and selective breeding of P. echinata for resistance to littleleaf disease. Athens, Ga.
2. Studies of racial variation in Pinus caribaea in resistance to fusiform rust and in P. palustris to brown spot disease. Saucier, Miss.
3. Selection, vegetative propagation and control breeding with mimosa for increasing resistance to mimosa wilt. Asheville, N. C.
4. Studies of racial variation in Pinus taeda. Brooklyn, Miss.

Florida Forest Service, Tallahassee, Fla.:

1. Adaptation tests of many tropical tree species for planting in South Florida.

Forestry Department, Alabama Polytechnic Institute, Auburn, Ala.:

1. Test of Pinus caribaea from Florida for planting in local area. Also, P. echinata and P. taeda from other states.
2. Tests of Pinus echinata x P. taeda hybrid with parent species in cooperation with Institute of Forest Genetics.
3. Techniques for vegetative propagation of Arizona cypress.
4. Cooperation with other agencies wishing to have custom-grown nursery stock produced from their own seed for planting on their areas.

Ida Cason Callaway Foundation, Hamilton, Ga.:

1. Selection and one-parent progeny tests of Pinus caribaea, P. palustris, P. taeda, and P. echinata.
2. Inter- and intra-specific crosses of selected trees of 4 major species of southern pine.
3. Selection of races of 4 major southern pines best suited to west-central Georgia.
4. Tests of introduced species.

Institute of Forest Genetics, Placerville, Calif.:

1. Controlled breeding of major southern pines.
2. Development of equipment and techniques for controlled breeding.
3. Studies in inheritance of characters in certain pines and other studies in field of forest genetics.

North Carolina Department of Conservation and Development, Division of Forestry, Raleigh, N. C.:

1. Test of Pinus pinaster for ocean beach planting.
2. Production of seed in a natural 50-year-old P. taeda stand developed

as a seed orchard by selecting and releasing the better trees.
3. Tests of methods and equipment for collecting cones and seed from standing trees.
4. Plus-tree selection by employees preparatory to conducting progeny tests.

Northeastern Forest Experiment Station, Upper Darby, Pa.:
1. Studies of racial variation in Fraxinus americana, F. pennsylvanica, and Acer rubrum.
2. Selection and controlled breeding of Fraxinus, Acer, Liriodendron, Pinus, and Quercus.
3. Testing of Pinus rigida x P. taeda and P. echinata x P. rigida hybrids in cooperation with Institute of Forest Genetics.
4. Development of equipment and techniques for controlled breeding.

Queensland Forest Service, Brisbane, Australia:
1. Studies of progeny after wind pollination of superior Pinus caribaea and P. taeda phenotypes.
2. Selection and controlled breeding for vigor and improved wood quality in Pinus caribaea, P. taeda, and other species.
3. Vegetative propagation of Pinus caribaea and P. taeda.

School of Forestry, University of Florida, Gainesville, Florida:
1. Examination of plantations of known seed source for information on racial strains of slash and longleaf pine.
2. Investigation on vegetative propagation.
3. Establishment of ecotype plantations of longleaf and slash pine for propagating and breeding material
4. Establishment of seed source plantations to demonstrate variations due to geographic origin.
5. Breeding slash and longleaf pine for vigor and form.

Southeastern Forest Experiment Station, Asheville, N. C.:
1. Studies of racial variation in Pinus taeda, P. echinata, and adaptability test of P. rigida x P. taeda hybrid. Buckingham, Va.
2. Adaptability tests of many coniferous species; also, Pinus monticola x P. strobus hybrid and P. rigida x P. taeda hybrid.
3. Limited study of racial variation in Pinus taeda and P. echinata and adaptability of P. echinata x P. taeda hybrid. Macon, Ga.
4. Vegetative propagation and selective breeding of Pinus caribaea and P. palustris to improve production of oleoresin and timber products. Lake City, Fla.

Southern Forest Experiment Station, New Orleans, La.:
1. Studies of racial variation in P. taeda. Bogalusa, La.
2. Studies of racial variation in vigor and resistance to disease in P. caribaea, P. taeda, P. echinata, and P. palustris. Cooperative studies located at Athens, Ga., Andulusia, Ala., and Lufkin, Texas.
3. Limited individual tree selection and controlled pollination of Pinus caribaea, P. taeda, P. palustris, P. echinata, at Alexandria, La., same less P. echinata at Gulfport, Miss., and Bogalusa, La.

4. Organizational responsibility for the 1951 South-wide study of racial variation in 4 major species of southern pine, in cooperation with the Committee on Southern Forest Tree Improvement.

Tennessee Valley Authority, Norris, Tenn.:

1. Adaptation test plantings of Castanea, Carya, and Corylus species under varying conditions.
2. Nursery selection of Pinus taeda, P. echinata, and P. strobus seedlings.
3. Studies in methods of inducing figured wood in Acer, Betula, Juglans, and Liriodendron species.
4. Vegetative propagation of numerous hardwood genera.
5. Studies of racial variation in Pinus taeda, Juglans nigra, Juniperus virginia, Rhammus purshiana, and Robinia pseudoacacia.
6. Plantings of foreign tree species to test adaptability or to serve as a source of pollen or seed.

Texas Forest Service, College Station, Texas:

1. Studies of racial variation in local Pinus taeda.
2. Selection and hybridization of selected Pinus taeda, P. palustris, P. echinata, and P. caribaea.
3. Tests of nursery bed selection of Pinus taeda, P. caribaea, and P. echinata.
4. Adaptation planting of many foreign species and hybrids.
5. Vegetative propagation of forest trees.
6. Phenological observations of four major southern pines.

University of Virginia, Blandy Experimental Farm, Boyce, Va.:

1. Studies of chromosome number and phylogeny in the conifers.
2. Studies of natural hybridity in the oaks.
3. Studies of racial variation in ash and maple.

West Virginia Pulp and Paper Company, Georgetown, S. C.:

1. Seed orchard in natural stand of Pinus taeda.
2. One-parent progeny tests with P. taeda.
3. Stimulation of seed production in P. taeda.
4. Tests of a few introduced species.

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TATION PAPER NO. 18 AUGUST 1952

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RE-ESTABLISHING PINE ON PIEDMONT CUT-OVER LAND

BY

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AND
T. C. NELSON

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina
E. L. Demmon,
Director

U. S. Department of Agriculture - Forest Service

RE-ESTABLISHING PINE ON PIEDMONT CUT-OVER LAND

by E. V. Brender and T. C. Nelson

The common practice of clear cutting merchantable-size pine stands frequently results in scrub hardwoods instead of a new crop of pines. The understory hardwoods, ever present in the merchantable pine stands of the Piedmont, soon close the canopy and exclude the successful establishment of pines. If a source of seed is available immediately after clear cutting, a new stand of pines may become established. However, it is estimated that at least 15 percent of the pine uplands in the southern Piedmont have reverted to brush and low value hardwoods. And this trend will increase as long as no provisions are made to restock the land with pine. Natural reseeding to pine can no longer be obtained on about two million acres, since a source of seed is not available or the understory hardwoods have obtained such a strong foothold as to preclude pine seedlings from becoming established. Planting will have to be resorted to if we want to grow pine on these acres. Even so, establishment of planted pines in recently cut-over woods, in competition with understory hardwoods, will never be as successful as old field planting. Some form of pretreating the planting site may be necessary to establish a satisfactory number of pines.

This paper deals with a study[1/] which had two major purposes: (1) to determine the effectiveness of certain preplanting treatments in permitting pines to come through hardwood competition, and (2) to compare survival and growth rate of planted loblolly and slash pine under the various treatments tested.

DESCRIPTION OF THE STUDY AREA

The study was carried out on the Casulon Plantation, near Bishop, Georgia. The area initially supported a stand of 90-year-old shortleaf pine, with understory hardwoods consisting chiefly of oaks, hickories, gums, and shrubby species such as dogwood, plum, haw and sumac. The understory hardwoods were small, mostly in the one-inch diameter class. On the average they gave direct overhead shade to over 17 percent of the area.

1/ The study was conducted in cooperation with the George Foster Peabody School of Forestry, University of Georgia, Athens.

Figure 1.--Merchantable stand of shortleaf pine with understory hardwoods.

Figure 2.--Pine overstory clear cut. Hardwoods dominate the area.

TREATMENTS

All of the merchantable pine was cut, leaving the understory hardwoods and a few scattered pine saplings. Immediately after removal of the pine overstory the area was treated and planted as follows:

Treatment A--control: Seedlings planted at 6 x 6-foot spacing, without prior treatment of hardwoods.

Treatment B--partial brush cutting and burning: All hardwoods 2 inches d.b.h. and larger were cut, the brush was piled, and the area was broadcast burned and planted at 6 x 6-foot spacing.

Treatment C--complete brush cutting: All hardwoods were cut, the brush left as it fell, and the area planted at 6 x 6-foot spacing.

Treatment D--complete brush cutting and grubbing: All hardwoods were cut and major roots and root collars grubbed out before planting at 6 x 6-foot spacing.

Treatment E--planted openings in the brush cover: Seedlings were planted in groups of three to six per opening, so that the same number of seedlings were planted as in 6 x 6-foot spacing.

The treatments were replicated in four randomized blocks, with 10 plots per block, each plot 0.15 acre in size. One plot in each treatment was planted to loblolly pine and the other to slash pine. The planted pine seedlings were remeasured at the end of the first, second, third, and fifth growing seasons. The seedling height was measured in tenths of feet; the position of seedlings (whether free growing, partially overtopped or completely overtopped) and the occurrence of fusiform rust and glaze damage were recorded.

RESULTS AT THE END OF THE FIFTH YEAR

The results at the end of the fifth year are summarized in tables 1 and 2. Number of trees have been converted to an acre basis to permit a more realistic comparison of degree of stocking.

Survival

Analysis shows that loblolly pine had a much higher survival rate under all conditions tested than slash pine. (This is also borne out by an old field planting on the Casulon Plantation with leftovers of the same planting stock, where loblolly had a survival of 86 percent as against 68 percent for slash pine.)

Table 1.--Survival and height growth of planted loblolly pines, by treatments

Treatment	All positions				Seedlings free to grow		
	Trees planted	Tree survival		Average height	Free seedlings	Survivors	Average height
	Number	Number	Percent	Feet	Number	Percent free	Feet
A 1/	1114	701	62.9	7.01	526	75	7.57
B	1143	840	73.5	8.01	748	89	8.35
C	1128	704	62.4	7.60	605	86	7.94
D	1158	816	70.5	7.99	792	97	8.06
E	1136	720	63.4	7.36	540	75	7.88
All treatments combined			66.6	7.65		85	8.00

1/
A. Control
B. Partial brush cutting and burning
C. Complete brush cutting
D. Complete brush cutting and grubbing
E. Planted openings in brush cover

Table 2.--Survival and height growth of planted slash pines by treatments

Treatment	All positions				Seedlings free to grow		
	Trees planted	Tree survival		Average height	Free seedlings	Survivors	Average height
	Number	Number	Percent	Feet	Number	Percent free	Feet
A	1202	516	42.9	5.61	356	69	6.10
B	1136	605	53.3	5.96	429	71	6.44
C	1158	428	37.0	6.11	291	68	6.66
D	1158	623	53.8	6.59	561	90	6.81
E	1136	588	51.8	5.46	388	66	6.04
All treatments combined			47.7	5.86		73	6.35

Comparison of the results of the preplanting treatments showed that treatments B (partial brush cutting and burning) and D (complete brush cutting and grubbing) resulted in significantly higher survival than other treatments or the control.

The results are somewhat obscured since the source of seed of the planting stock of both species is unknown. However, the relatively greater survival and greater juvenile height growth of loblolly pine over slash pine is in agreement with the findings of other investigators.

A study made in the Alabama Piedmont (1) shows that loblolly grows faster than slash pine up to an age of nine to ten years. After that slash pine grows slightly faster than loblolly pine. The average survival for loblolly in the Alabama study was 83.2 percent, while for slash it was 52.9 percent.

Another study made in Tennessee (2) quotes survival of loblolly pine as 80 percent and slash pine as 47 percent.

In Central Louisiana (3) it was found that loblolly survived better than slash pine. At 10 years of age, planted loblolly exceeded slash pine in height by 3 feet on unburned areas, while on burned areas slash pine was 1 foot taller than loblolly pine.

At Watkinsville, Georgia (4) survival of 6-year-old loblolly pine was 88 percent, while that of slash pine was 61 percent. The respective heights were 13 feet and 10 feet.

Seedlings Free to Grow

Without cleaning, as indicated in table 1 by the number of free seedlings after 5 years of growth, loblolly pine planted in openings or without area preparation could not meet a standard of 600 free-growing seedlings per acre. Some brush or ground treatment is necessary, and the number of free seedlings appears to increase with intensity of treatment. Brush cutting alone is satisfactory, but 25 to 30 percent more free seedlings may be obtained with the additional treatment in burning or grubbing. Cleaning would assure well over 600 free seedlings per acre in any treatment class.

By the same standard, satisfactory stocking of slash pine cannot be expected without cleaning, although brush cutting followed by grubbing approaches it. The statistical difference between loblolly and slash pine in number of free seedlings per acre is highly significant.

Figure 3.--Loblolly pine seedling outgrowing hardwoods on check plot.

Figure 4.--Slash pine seedling free to grow.

Height Growth

Loblolly showed superior height growth over slash pine. Statistically, the difference is highly significant. The average height of the loblolly seedlings at the end of the fifth growing season was 7.65 feet, while slash pine was only 5.86 feet in height. The free seedlings averaged 8.00 feet, and 6.35 feet respectively. There is also a trend indicating that for both species the preplanting treatments stimulated height growth. The greater height of loblolly pine accounts in part for a greater percentage of free seedlings among survivors.

FUSIFORM RUST AND GLAZE DAMAGE

The study was not designed specifically to furnish information on damage from fusiform rust and glaze, but observations on these two items were collected and the results are given here.

Twenty-one percent of the slash pine had branch or stem cankers of fusiform rust as compared with 14 percent on loblolly pine. As for wind and glaze damage, 3 percent of the surviving slash pines were loose at the root-collar. Such seedlings are reclining at a small angle with the ground and have no chance of recovering. Less than 1 percent of the loblolly seedlings are in a leaning position. Their root-collars are firm, and most of them will straighten out.

SUMMARY AND CONCLUSIONS

Clear-cut upland pine stands which contain a relatively light understory of hardwoods can be successfully planted in the lower Piedmont to either loblolly or slash pine, provided the planting is done immediately after the clear cutting. In this study area, the amount of ground shaded by understory hardwoods increased from 17 percent to 34 percent during the first two growing seasons following the harvest cutting of the pine. Early release cuttings after planting are essential if adequate standards of survival and growth are expected.

Loblolly pine, under lower Piedmont conditions, survives better and displays greater juvenile height growth than slash pine. This conclusion cannot be accepted at its full value from this study alone, since the seed source of the planting stock of both species is unknown. However, other studies in the Piedmont confirm the superiority of loblolly pine.

Certain preplanting treatments proved to be helpful in establishing a greater number of seedlings, of either species, free from overhead shade. The most successful treatment was cutting and grubbing, which provided nearly 800 free loblolly seedlings per acre, and 560 free slash pine seedlings per acre. Cutting all hardwoods 2 inches and larger, followed by broadcast burning, provided about 750 free loblolly seedlings per acre, and 430 free slash pine seedlings per acre. The cutting of the brush alone was no better than no treatment.

It must be remembered that the preplanting treatments were applied on small plots with hand tools. In actual practice the cutting and grubbing treatment could be done with a Marden brush cutter or a similar machine. The cutting and burning treatment when carried out on a larger scale would also create a hotter burn. In either case, the expected results should be equally as good as those obtained on the small plots, or better. There are other modifications which would be applied under actual practice. For instance, hardwoods above 4 inches d.b.h. would more than likely be poisoned with ammate or 2,4,5-T. This would reduce competing sprouts which crowded out some planted pine seedlings in the test plots.

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Agriculture-Asheville

TATION PAPER NO. 19 OCTOBER 1952

A Guide to the Hitchiti Forest Research Center

by

Ernst V. Brender

FOREST SERVICE

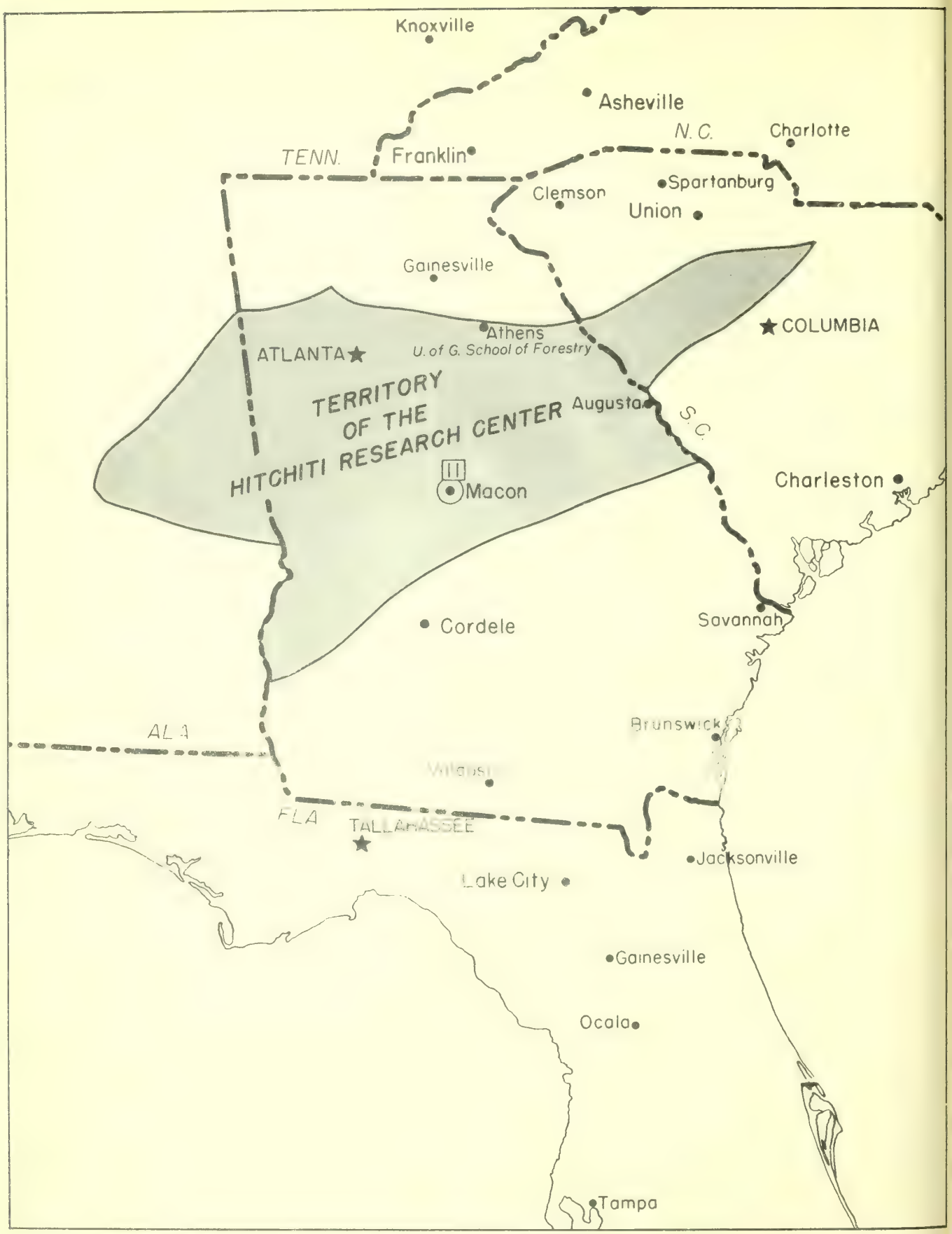
U. S. Department of Agriculture

Southeastern Forest Experiment Station

Asheville, North Carolina

E. L. Demmon,

Director



Cover:

About one-third of the forest in the lower Piedmont consists of relatively young pine stands which sprang up in cotton fields that were abandoned because of the boll weevil.

GUIDE TO THE HITCHITI FOREST RESEARCH CENTER

by

Ernst V. Brender

The Hitchiti Forest Research Center was established in 1946 by the Forest Service, USDA, to find ways and means of producing more wood in the depleted forests of lower Piedmont Georgia, Alabama, and South Carolina. Sixty percent of the 18-1/2 million-acre territory is in forest. The forest consists principally of even-aged stands of loblolly pine on the uplands and a mixture of oaks, hickories, yellow-poplar, and other hardwoods on the moist sites.

An estimated 40,000 people are directly engaged in harvesting and processing the forest products from this area, and 11 percent of the total income is obtained from timber products. The secondary business and industry derived from forest enterprise (such as truck and rail transportation, making paper and plywood and hickory tool-handles, selling axes and tractors) raises the total considerably. But a much greater increase in business and revenue could come from doubling the annual production of the forests--an entirely feasible and practical possibility. The question is, how can it be done most quickly and most cheaply.

The forest research center exists to work on the answers to such questions. It combines biology, economics, soil science, industrial harvesting techniques, and many other specialties. Most of the staff are trained foresters. The main office is in Macon, and the greater share of the experimental work is being done on the 4,735-acre Hitchiti Experimental Forest 18 miles out of Macon.

Originally, the Piedmont was a fertile land of fine oak-hickory forest. Natural springs were numerous; branches, creeks, and streams flowed clear and cool. Intermixed with the oak-hickories were beech, maple, chestnut and shortleaf pine. The forest had reached a climax; many individual trees were 2 to 3 feet in diameter and 120 feet in height. In the understory were dogwood, azalea, huckleberry, and chinquapin (no imported Japanese honeysuckle as yet). Starting about 1773, waves of settlers rapidly advanced from the east coast. Within a 50-year period, the Piedmont was converted from a primeval forest to a farming country. Since those days, 87 percent of the land has been cleared or cultivated one or more times. The original topsoil, which was from 7 to 15 inches deep, has entirely disappeared from many acres. Row cropping, particularly for cotton, caused serious erosion even in the early days. An erodable topsoil and even more erodable subsoil, gully-washing rains of extreme intensity, continual freezing and thawing action in winter, hot summers bringing high soil temperatures and rapid oxidation of humus--all these meant that the delicately balanced land lost its fertility when it was without plant cover. A serious agricultural slump occurred in the late 1880's. With the arrival of the boll

weevil in 1920, land abandonment took place at an unheard-of rate. Pines seeded in naturally on old fields, and it was thus that some of our present-day forests got their start. Land abandonment has continued off and on ever since, until approximately 10 million acres of this territory are in forest again. Deep in the tracts of young pines one comes across massive, wide-armed oaks shading the ruined chimney that marks an old "home place." Mile after mile of former farmland, in unbroken 10-, 20-, and 30-mile stretches has gone back to woods. It is because of this forest that the future of the area is so closely tied to forest production and forest management.

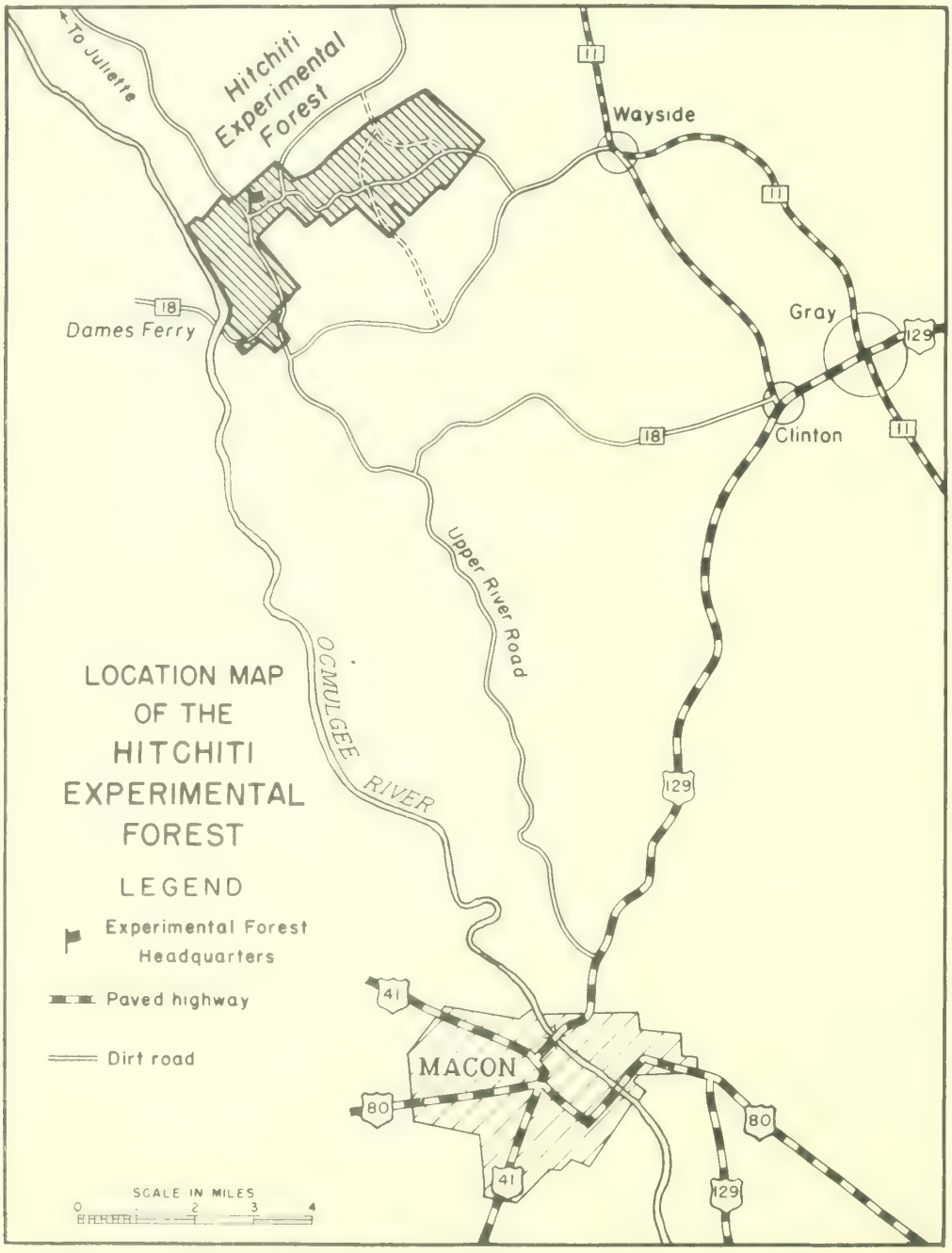


Figure 1.--The experimental forest is 18 miles from Macon.

THE FOREST IN THE RESEARCH CENTER TERRITORY

Some of the better forests of the region are usually found in relatively large tracts of 5,000 acres and more. However, 65 percent of the forest land is in farm ownership of numerous small tracts. These woods are often severely depleted. In consequence, the average growing stock of the forests in this area in 1946 was only 1,800 board feet per acre, of which pine made up 70 percent and the hardwoods 30 percent in volume. During the decade from 1936 to 1946, the pine saw-timber volume decreased 35 percent. It has been estimated that following present logging practices, one acre out of two reverts to low-value hardwoods. Fortunately, the area still has a large area of so-called boll weevil timber, which for the time being forms a backlog of forest capital. Headway is being made in establishing extensive forest plantations which promise to be of importance to the future timber supply. The big challenge is to learn to restore the productivity of the large acreage of depleted woods, and to properly manage the smaller acreage of desirable woods.

FOREST MANAGEMENT OPPORTUNITIES

The scientific management of the resource which contributes so much to the economy of this area has been very much neglected. It has frequently been pointed out that only about one-third as much usable wood is being grown in this area as the land is capable of producing. Instead of growing 500 board feet per acre annually, we are only growing about 150 board feet; instead of growing one cord per acre, we are only getting one-third cord per acre.

This low growth rate is, in part, the result of liquidating cutting practices. It is also due to lack of appreciation of what the timber-growing possibilities are in this territory. Some of it must also be attributed to invasion of our forests by weed species, such as low-value hardwoods, shrubs, and vines. Still other losses are due to natural enemies of the forest, such as insects and diseases. And finally, wildfires destroy millions of seedlings, thousands of saplings, poles, and sometimes saw-timber trees.

We want to find what method of harvesting timber is best suited for perpetuating pine. Under which method will the most volume be grown, the greatest net-returned be reaped? What is the optimum spacing for pine trees throughout the life of the stand--for growing pulpwood--for growing saw timber? What measures are necessary to control weed species? Can we stimulate seed production, and can we create a receptive seedbed for germinating pine? How can these measures be applied economically? Which management practices are best for farm woodland owners? Can we select superior strains of pine, can we develop superior hybrids? These and many more problems need to be solved.

THE RESEARCH PROGRAM

Management of Loblolly Pine

Comparison of management systems on 40-acre compartments

Survey study of reproduction (growth, damage, mortality) in shelterwood stands

Survival, growth and development of residual saplings on areas clear cut and planted

Stand Improvement in Loblolly Pine

Relationship of growth to stand density, site, and age in thinned and unthinned stands

Bud and branch pruning

Regeneration

Site preparation for hardwood control before planting clear-cut areas

Field tests of hybrid pines

Seed production by stand characteristics

Behavior and control of honeysuckle

Silvics

Prescribed burning as a silvicultural tool and its effect upon soils

Financial Aspects

Farm woodlot management (4 woodlots)

Relation of harvesting costs to tree size, volume cut per acre, topography, etc.

Determining conversion values of trees for alternate uses

Development of log and tree grades

Forest valuation (proposed), growth studies, land use, etc.

THE FOREST LABORATORY

The field laboratory on which many of the studies of this research center are conducted is the 4,735-acre Hitchiti Experimental Forest. It is situated along the east banks of the Ocmulgee River, 18 miles north of Macon, Georgia. The forest derives its name from a tribe of Indians who formerly lived in the area.

Climate and Soils of the Experimental Forest

Climate

The climate in the lower Piedmont is well suited to the growth of pine timber. The mean annual rainfall on the forest is about 48 inches. However, spring droughts of 4 weeks' duration may be expected in one out of every 5 years. Mean annual temperature is 63 degrees F., with extremes ranging from 6 degrees F. to 105 degrees F. The growing season lasts 7-1/2 months.

Topography

The topography is typical of lands bordering the major streams in the lower Piedmont. It is characterized by deep, narrow valleys, rounded ridges, and steep slopes. The lowest elevation on the experimental forest is 328 feet; the highest point on the plateau is 532 feet above sea level.

Soils

The soils occurring on this forest are representative of those of the principal watersheds of the lower Piedmont. They are found in the following proportions:

Soil series	Percent occurrence
Lloyd and Davidson	31
Vance	27
Madison and Cecil	20
Wilkes and Louisburg	12
Alluvial and Colluvial	9
Miscellaneous	1

The Lloyd and Davidson soils are dark, chocolate-colored soils. They are fertile and well drained. They are not as erodable as some of the other Piedmont soils. The Vance soils are light colored, with compact subsoils which retard root penetration and water movement. These soils are subject to severe erosion. The Madison and Cecil soils are the well-known, picturesque, red clay hills of Georgia. They are deep soils of good structure, well drained, and moderately productive. They are highly susceptible to erosion under agricultural abuse. The Wilkes and Louis-

burg soils are shallow, undeveloped soils, with frequent outcrops of parent rocks. They are agriculturally unproductive soils. Alluvial and Colluvial soils occur as narrow branch bottoms and in depressions. There are no extensive flood plains on the experimental forest.

Various degrees of erosion are found on all of these soils. On 20 percent of the area the topsoil is completely gone. An additional 70 percent retains only a thin layer of topsoil. Gullies are numerous and traces of the old cotton-field furrows are visible here and there throughout the forest.

The Timber Stand

Practically the entire forest is second-growth, 11 percent becoming established during the War between the States, 32 percent originating during the depression years of the late 1880's up to World War I, and 34 percent coming in since the arrival of the boll weevil in 1920.

The principal types are loblolly-shortleaf, and loblolly-hardwoods. The loblolly makes up 85 percent of the pine overstory, shortleaf 15 percent. Overstory hardwoods in these stands are confined more or less to stream banks, gullies, and old house places. Understory hardwoods are encroaching on 40 percent of the upland pine forest area. This invasion of hardwoods ties in with the age of the pine overstory, with exposure and degree of slope and the drainage pattern of the land. Roughly, about 10 percent of the forest is classified as hardwood stands, where the hardwoods make up over 80 percent of the dominant canopy.

The pine stands are mostly even-aged, where the trees on a given acre vary no more than 10 years in age. Only about 8 percent of the pine stands are many-aged in character, where seedlings, saplings, poles, and saw timber occur intermixed on a given area. Of the even-aged stands about 70 percent are fairly well stocked with either seedlings, saplings, poles, or saw timber, and 30 percent are definitely understocked. The average volume is about 4,000 board feet per acre, with a range from 800 to 22,000 board feet. On this forest, indications are that the average yearly growth of merchantable stands exceeds 500 board feet per acre, or one cord per acre. And still this forest is not yet fully productive. Many stands are understocked, and the quality of many trees is poor. The full production potential has not yet been reached.

Loblolly Pine Management Studies on the Experimental Forest

The research program on this experimental forest emphasizes investigations on how to manage loblolly pine for various owner objectives, such as growing maximum volume in the form of pulpwood and small sawlogs as against growing quality timber, like poles and piling, or high grade lumber.

The silvicultural as well as the economic aspects associated with these objectives are being evaluated. Under silvicultural aspects are included two broad systems of managing loblolly pine--the selection system or many-aged management, versus even-aged management.

Figure 2.--To gauge results of various cutting methods on compartments, all trees 6 inches in diameter and larger are measured at 5- and 10- year intervals.

Many-aged Management

Under many-aged management, a harvest cut is made at 5-year intervals (fig. 2), removing the growth that accrues during that period, in such a manner as to bring about an all-aged or selection type of forest on each acre.

Even-aged Management

Under even-aged management, different harvesting methods are being explored (fig. 3).

1. Clear cutting and planting: The entire crop, saw timber, and pulpwood, is being removed at a given rotation age, (tentatively set at 40 years) and the area is immediately planted to pine.

2. Seed tree method: All merchantable trees, saw timber, and pulpwood, are harvested when the stands are 50 to 60 years old, with the exception of 6 good seed trees per acre which are left for the purpose of restocking the area.

3. Shelterwood cutting: By this method 22 large seed trees or 40 small seed trees are left per acre to restock the area. These residual trees are removed when an adequate stand of seedlings is established.

Economic Aspects

These tests are made on logging chances of about 40 acres each so that the economics of harvesting a timber crop by these systems and methods of management can be evaluated.

Levels of Cultural Practices

In order to get maximum volume or highest quality, a stand has to be tended. Certain cultural practices must be applied throughout the life of the stand. Such practices include seedbed preparation, release cuttings, hardwood control, thinnings, and improvement cuttings.

Two levels of cultural care are given the stands under each method of management. One is a high level which is intended to assure success of the management method employed. The other is a moderate level designed to provide the best success possible at reasonable cost and does not include any treatment that will not pay for itself now. The purpose of these two levels is to determine whether additional expenditures above the absolute essentials will pay off in terms of added yields.

The loblolly pine management study area is shown in Figure 3 of this report. A more detailed description of studies, treatments, and results follows.

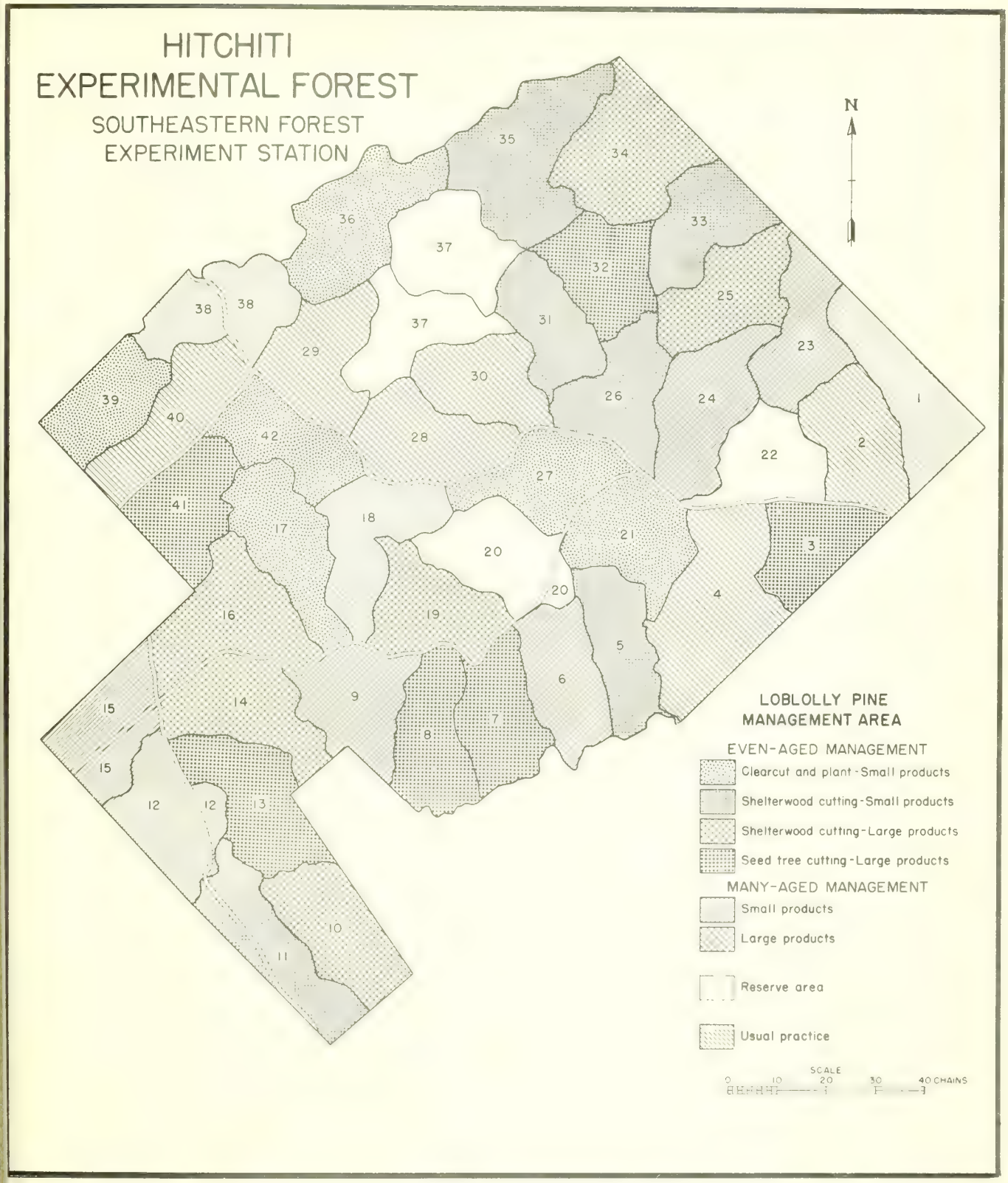


Figure 3.--A major study on the experimental forest is a long-time comparison of different management systems on compartments of about 40 acres each.

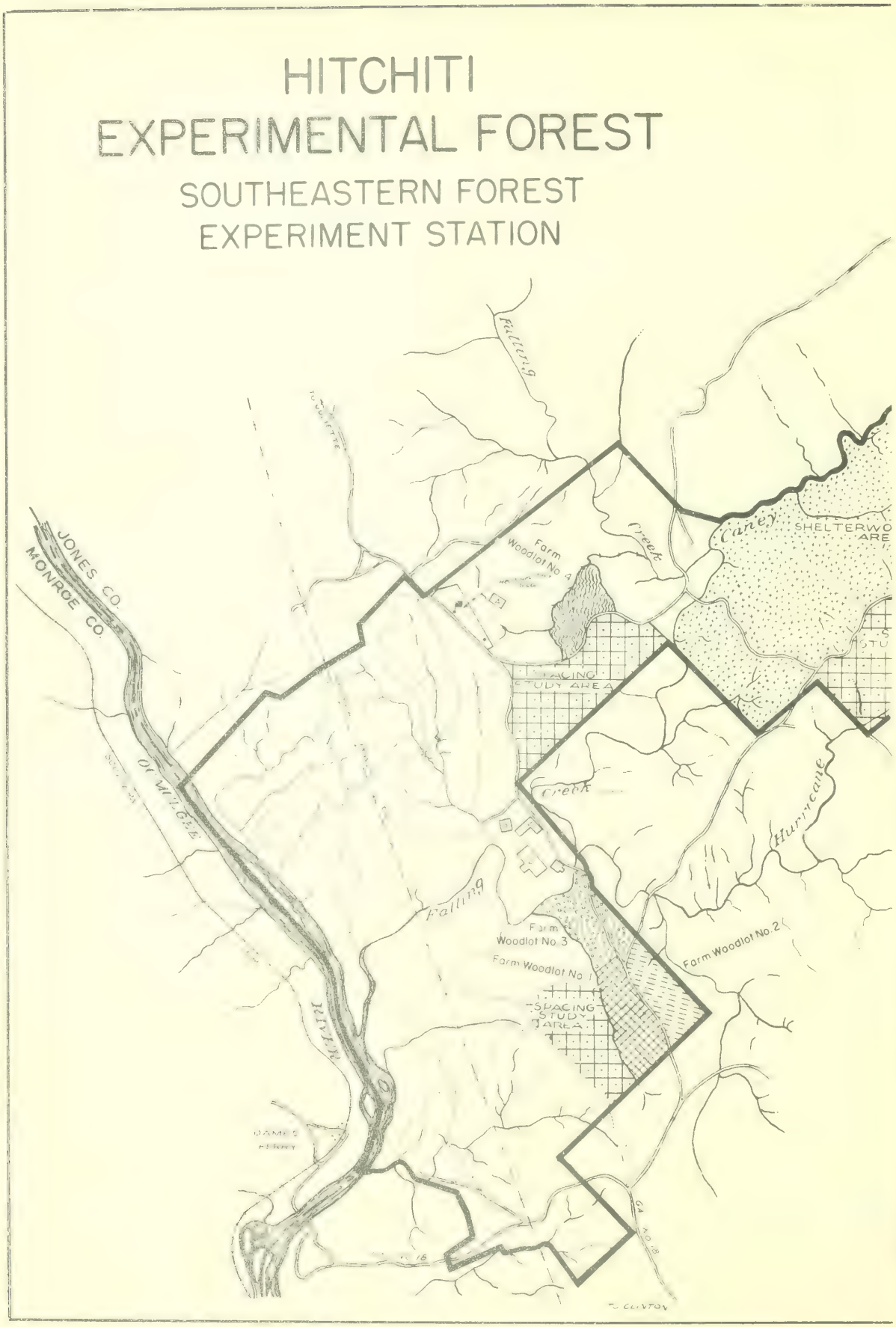
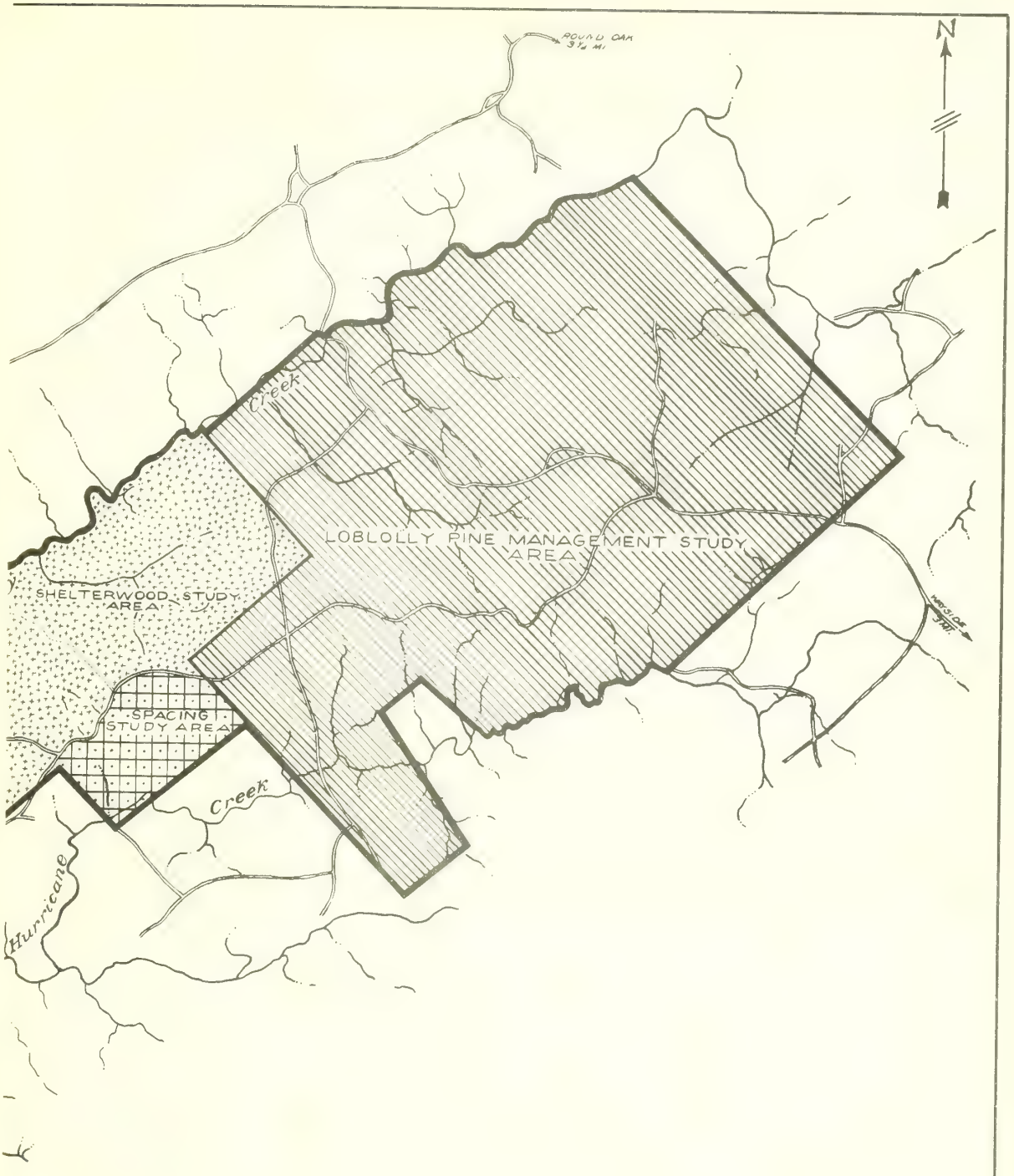


Figure 4.--Location of special studies on the experimental forest.



SPECIAL STUDIES

1. Hybrid pines.
2. Conventional pruning of loblolly pine.
3. Growing space plots.
4. Bud-pruning of loblolly pine.

SCALE
0 10 20 30 40 50 60 70 80 chains

Observation Point, Compartment 19, Loblolly Pine

Treatment

Even-aged management, shelterwood method, large saw timber objective, high level of cultural practices (fig. 5).

Shelterwood harvest cut made in winter of 1949. Left 27 trees per acre, with a volume of 3,160 board feet.

Stand History--per-acre data (pine only)

	Saw timber		Pulpwood		Topwood
	Total stand	Cut	Total stand	Cut	Cut
	Bd.ft.	Bd.ft.	Cords	Cords	Cords
Stand - 1946	5,720	941	4.1	-	-
Stand - 1949	6,090	2,930	4.6	4.1	0.7

Growth

The average annual growth per acre during three growing seasons, 1947 to 1949 inclusive, was 437 board feet, plus 0.3 cords of pulpwood which includes usable topwood.

Cultural Practices

In September 1950, 29 low-value hardwoods per acre, averaging 5.4 inches at breast height (d.b.h.) were treated with ammate at a cost of $1.59 per acre.

Figure 5.--Shelterwood method of harvesting timber in Compartment 19, 3 years after cutting. Pine seedlings are still hidden in grass.

Observation Point, Compartment 21, Loblolly Pine

Treatment

Even-aged management, clear cutting and planting, small saw timber and pulpwood objective, high level of cultural practices (fig. 6).

Clear cut and planted in the winter of 1948.

Stand History--per-acre data (pine only)

	Saw timber		Pulpwood		Topwood
	Total stand	Cut	Total stand	Cut	Cut
	Bd.ft.	Bd.ft.	Cords	Cords	Cords
Stand - 1945	6,970	1,903	5.1	-	-
Stand - 1948	5,325	5,325	1/5.7	4.4	2.1

1/ Some of this wood was not harvested because it was too small for profitable operation.

Growth

The average annual growth per acre was 1.1 standard cords.

Cultural Practices

Brush disposal.--The tops and branches left from logging were piled and burned to permit immediate planting.

Planting.--As a result of brush disposal, 20 percent of the area could be machine planted at operating costs of $4.26 per acre, while the remainder was hand planted at a cost of $9.64 per acre.

Hardwood control.--In August 1950, the worthless hardwoods were poisoned with ammate at a cost of $1.76 per acre. Forty-seven trees per acre, from 3 inches d.b.h. and up, were treated.

Figure 6.--Compartment 21, clear cut and planted in 1948, changed from pine straw litter to broomsedge in one year. Pine seedlings are now again crowding out the broomsedge.

Observation Point, Compartment 27, Loblolly Pine

Treatment

Even-aged management, clear cutting and planting, small saw timber and pulpwood objective, low level of cultural practices.

Clear cut and planted in winter of 1949.

Stand History--per-acre data (pine only)

	Saw timber		Pulpwood		Topwood
	Total stand	Cut	Total stand	Cut	Cut
	Bd.ft.	Bd.ft.	Cords	Cords	Cords
Stand - 1945	5,294	1,174	5.6	-	-
Stand - 1949	5,388	5,388	5.7	5.7	1.5

Growth

The average annual growth during a 3-year period was 401 board feet per acre, or expressed in terms of pulpwood, 1.2 cords.

Cultural Practices

Brush disposal.--Branches and tops left from logging were piled in windrows and put into gullies at a labor output of 10 man-hours per acre.

Planting.--Full stocking was obtained by planting between windrows. Planting machine could have been used on 36 percent of the area, where slope and soil were suitable.

Hardwood control.--In August 1950, the worthless hardwoods 5 inches and larger were treated with ammate at a cost of $0.93 per acre.

Observation Point, Compartment 24, Loblolly Pine

Treatment

Many-aged management, tree selection cutting, 5-year cutting cycle, small product objective.

Stand History--per-acre data (pine only)

	Saw timber		Pulpwood		Topwood
	Total stand	Cut	Total stand	Cut	Cut
	Bd.ft.	Bd.ft.	Cords	Cords	Cords
Stand - 1944	6,242	1,974	4.8	-	-
Stand - 1950	6,089	1,538	5.5	0.2	0.4

Growth

The average per-acre growth over a 4-year period was 479 board feet, plus 0.5 standard cords of pulpwood.

Cultural Practices

In July 1951, 48 hardwood stems per acre, averaging 4 inches d.b.h., were poisoned with ammate at a cost of $1.70 per acre.

Observation Point, Compartment 29, Loblolly Pine

Treatment

Many-aged management, individual tree selection cut, large product objective, high level of cultural measures (fig. 7).

Cutting made in winter of 1946-47.

Stand History--per-acre data (pine only)

	Saw timber		Pulpwood		Topwood
	Total stand Bd.ft.	Cut Bd.ft.	Total stand Cords	Cut Cords	Cut Cords
Stand 1947	7,726	2,602	4.7	1.8	.4

Hardwood Control

In the spring of 1951 openings created by the improvement cut made in 1946 were treated to release pine seedlings which had come up in these openings. An average of 50 trees per acre were treated at a cost of $2.30.

Pine Seedling Establishment

Four years after the harvest cut, a sample survey on 9 acres disclosed the following:

1.) Twenty-one percent of the area is in openings, which resulted mostly from the cutting of large, mature trees.

2.) The average size opening, between perpendicular crown projections, is 35 feet.

3.) Ninety-three percent of the openings are well stocked with thrifty seedlings.

4.) The average height of the dominant seedlings at the end of the fourth growing season is 3 feet.

Figure 7.--Selective logging in Compartment 29. Pine seedlings established in openings since logging in 1946. Competing understory hardwoods treated with ammate.

Observation Point, Compartment 41, Loblolly Pine

Treatment

Even-aged management, seed tree cutting, large product objective, high level of cultural measures (fig. 8).

Seed tree cut made in winter of 1950-51, leaving six seed trees per acre, with 1705 bd. ft.

Stand History--per-acre data (pine only)

	Saw timber		Pulpwood		Topwood
	Total stand	Cut	Total stand	Cut	Cut
	Bd.ft.	Bd.ft.	Cords	Cords	Cords
Stand - 1946	7,419	2,413	2.8	-	-
Stand - 1950	8,151	6,100	3.1	2.9	1.1

Growth

The average annual growth rate during the past 4 years was 786 bd. ft. per acre.

Cultural Practices

In August 1951, 41 hardwood stems per acre, averaging 5 inches d.b.h., were poisoned with ammate crystals at a cost of $1.86 per acre.

Figure 8.--Seed-tree cutting in Compartment 41. Seed trees were carefully selected for fruitfulness and good form.

Farm Woodland Management

Investigations of forest management in the Southern Piedmont would be incomplete without considering the problems connected with the management of farm woods. The economic aspects of managing them are emphasized in our research work.

What are the returns to the farmer from selling stumpage and from harvesting and selling cut products?

What frequency of cutting is best suited for his business?

What kind of products can he grow best?

To answer these questions, four farm woodlots are under intensive management on this experimental forest. They differ from each other in amounts of initial growing stock and in the numbers of worthless hardwoods.

Initial growing stock per acre in 1948 was as follows:

Woodlot	Area	Pine				Hardwood
		Total	Saw timber	Cordwood	Trees	Trees
	Acres	Cu.ft.	Bd.ft.	Std. cords	Number	Number
1	40	2,047	7,967	4.5	85	8
2	43	1,461	5,206	4.1	73	29
3	43	902	2,666	3.9	67	26
4	30	441	104	5.6	91	7

Group Selection

Three of the woodlots are managed by the group selection method, on an annual cutting cycle. One-fifth of the area of each woodlot is cut over each year, harvesting no more than the annual growth from the entire woodlot.

After the fifth annual harvest cut, woodlot No. 2 will be harvested at 5-year intervals only.

Pulpwood Rotation

Woodlot No. 4 is managed on a 30-year pulpwood rotation by clear cutting and planting 1 acre each year. Occasionally, additional areas on this 30-acre woodlot may need to be thinned.

Figure 9.--A mature stand in farm woods being marked for harvesting by group selection.

Financial Returns

The first three annual harvests combined gave stumpage returns of $600.95, $328.10, and $160.10 for woodlots 1, 2, and 3. The respective roadside values were $1,021.89, $639.34, and $300.00. This reflects annual gross returns of $8.52, $4.96, and $2.33 per acre.

The location of these woodlots is shown in figure 4.

Special Studies

Numerous problems encountered in the management of a forest cannot be solved by large-scale tests.

Consequently, detailed studies are under way to solve more specific silvicultural and economic problems. These studies are designed so that they can be statistically analyzed and the significance of results evaluated.

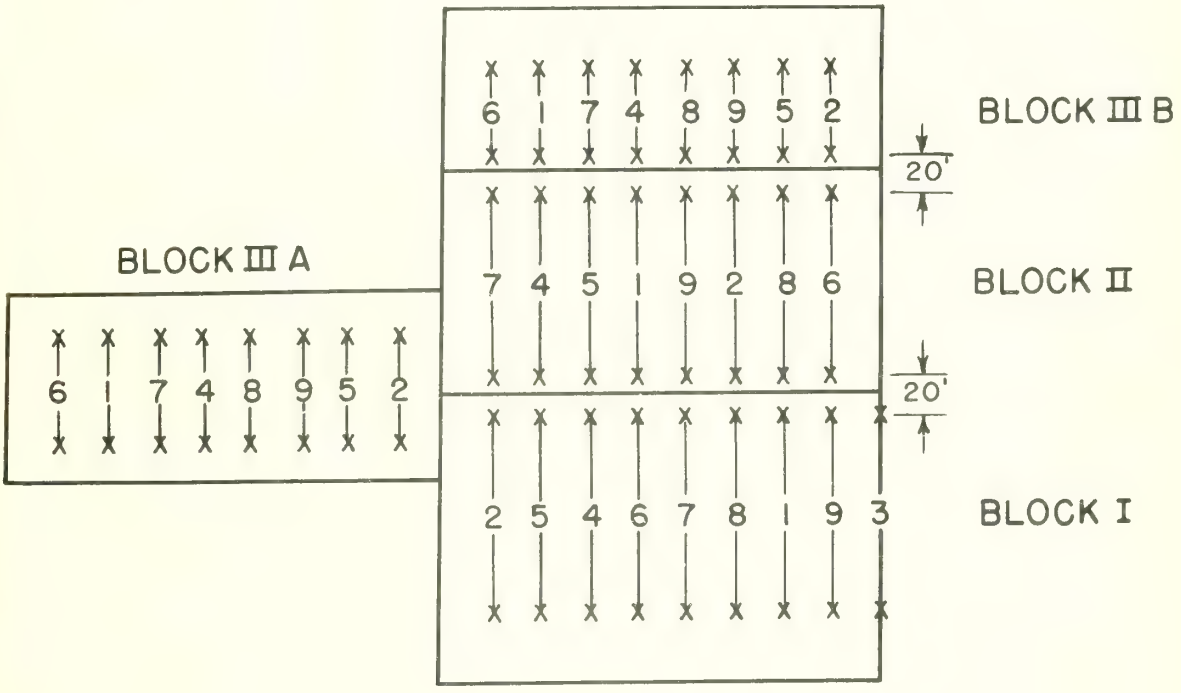
Their location is given in figure 2, and observation points are employed to describe them.

Special Studies, Observation Point No. 1

Hybrid Pines

Recent studies have shown that there are different geographic races within the loblolly and shortleaf pine species. This in turn brings up the possibility of breeding for faster growth rates, better seed production, improved form, increased disease resistance, and other superior traits.

Seedlings from several hybrids of shortleaf and loblolly pine were planted in the spring of 1951 to test them against examples of the parent species from different localities. The experimental design for the progeny tests of these hybrids is shown below:



Row 2 is shortleaf pine.
Rows 5, 8, and 9 are loblolly pine from different localities.
Rows 1 and 6 are crosses of shortleaf and loblolly pine.
Rows 4 and 7 are shortleaf loblolly hybrids backcrossed with loblolly.
Row 3 is a shortleaf-loblolly hybrid, self fertilized.

Special Studies, Observation Point No. 2

Conventional Pruning by Two or More Operations

Many areas in the Piedmont are only partially stocked with limby trees which are worthless for the production of lumber.

Is it economically practical to prune these trees so that clear lumber will be grown?

When should pruning be done--at a time when a clear 16-foot log can be pruned in one operation, or in two or more operations before the limbs get large and while the core of the stem is small?

How much of the live crown can one prune at a time without killing the tree or reducing its growth unduly?

What is the final value of lumber of a pruned tree versus an unpruned tree?

These are some of the questions under consideration here. There are eight blocks of five 1/10-acre plots where the following tests are being made:

1. Pruning 1/2 total height in summer in two or more operations.
2. Pruning 1/2 total height in winter in two or more operations.
3. Pruning 2/3 total height in summer in two or more operations.
4. Pruning a full 16-foot log by 2/3 height pruning in one operation.
5. No pruning.

The study was started in 1945. Three prunings have been applied so far. The two-thirds height pruning is 70 percent completed, half-height pruning is 42 percent completed, two-thirds height in one operation is 97 percent completed.

Special Studies, Observation Point No. 3

Spacing and Thinning Study

Of paramount importance to timber growers is a knowledge of growth that can be obtained under various degrees of stocking. Growth rate is influenced by the spacing of the trees, their age, and the site upon which they grow (fig. 10).

Figure 10.--Two plots, of a series of 72, designed to determine optimum spacing for saw-timber or pulpwood objectives. A shows low density of residual stand. B is high density.

To determine what the growth rates are under various combinations of the above conditions, 72 quarter-acre plots were established in the winter of 1948-49. Some of the plots were thinned to correspond to densities of other unthinned plots. This study is part of a region-wide study which will result in information on expected yields from loblolly pine under various conditions.

Two of the plots are described in detail below:

Plot number	Age	Site Index	Average d.b.h.	Initial BA/acre	Volume Cut	Residual BA/acre
	Years	Feet	Inches	Sq.ft.	Cords	Sq.ft.
63	28	80	6.9	181	5.9	135
64	26	85	8.0	158	14.9	98

Additional Studies

At the Casulon Plantation near Bishop, Georgia, an interesting study of bud-pruning slash pine, to develop knot-free lumber, is nearing completion. Another study, nearly completed, is to determine whether certain preplanting treatments in young hardwood areas are beneficial for establishing planted pines.

On the Hitchiti Experimental Forest, a bud-pruning study of loblolly pine has been started. A small study is in progress to determine what happens to the unmerchantable pine saplings left after clear cutting.

Figure 11.--Japanese honeysuckle in Piedmont forests is increasing.

Figure 12.--Detailed study of shelterwood condition often found in the lower Piedmont.

Control of Japanese honeysuckle, which prevents the establishment of pine seedlings, is also being investigated (fig. 11).

Another study is intended to show how best to handle the more open-grown pine stands that have a heavy understory of pine seedlings. The purpose of the study is to find out how well and how long pine seedlings can thrive under various degrees of pine overstory shade, how seedlings respond to release, and what damage they suffer from logging operations (fig. 12).

The controlled use of fire as a possible tool for checking invasion of undesirable hardwoods, and its effect upon the soil, are subjects of a cooperative undertaking between several research centers and the Georgia Experiment Station.

Another cooperative enterprise, with participation by the Southern Pine Inspection Bureau, deals with determining lumber-grade yields for a new set of pine log and tree grades that were developed in cooperation with the Southern Forest Experiment Station.

At Hamilton, in west-central Georgia, the Station and the Ida Cason Callaway Foundation are cooperating on a broad-scale tree improvement study that occupies a graduate forester full time. Emphasis is on the four principal southern pines, longleaf, slash, loblolly, and shortleaf. The first step was to locate trees that seem to have outstanding growth rate, vigor, form, and disease resistance. Next step is to test their progeny to see whether these traits are inherited. After superior strains that breed true to type have been proven, seed will be produced in quantity. Nearly 300 outstanding mother trees have been selected from natural stands and plantations on a 35,000-acre property. Eight thousand seedlings grown from seed of these selected trees were outplanted in 1951, and additional seed was sown in the nursery in 1952. Also, controlled pollinations have been made between outstanding individuals of all four species.

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ATION PAPER NO. 20 DECEMBER 1952

SUGGESTED PROJECTS IN THE GENETIC IMPROVEMENT OF SOUTHERN FOREST TREES

BY

THE COMMITTEE ON SOUTHERN
FOREST TREE IMPROVEMENT

FOREST SERVICE

U. S. Department of Agriculture

Southeastern Forest Experiment Station
Asheville, North Carolina
E. L. Demmon,
Director

This publication was prepared by the Committee on Southern Forest Tree Improvement to assist those who might take part in forest genetics research.

Previous publications and reports prepared by or for the committee are:

1. Report of the first southern conference on forest tree improvement. Atlanta, Ga., January 9-10, 1951. Mimeographed. U. S. Forest Service, Atlanta, Ga.

2. Proposal for a cooperative study of geographic sources of southern pine seed. Subcommittee on Geographic Source of Seed, Philip C. Wakeley, Chairman. Mimeographed. Southern Forest Experiment Station, New Orleans, La. Oct. 25, 1951.

3. Standardized working plan for local tests of seed source. Subcommittee on Geographic Source of Seed, Philip C. Wakeley, Chairman. Mimeographed. Southern Forest Experiment Station, New Orleans, La. Oct. 25, 1951.

4. Hereditary variation as the basis for selecting superior forest trees. Keith W. Dorman, Chairman, Subcommittee on Tree Selection and Breeding. Southeastern Forest Experiment Station, Station Paper No. 15. March 1952.

5. Directory of forest genetics activities in the South. Keith W. Dorman, Chairman, Subcommittee on Selection and Breeding. Southeastern Forest Experiment Station, Station Paper No. 17. March 1952.

6. Working plan for cooperative study of geographic sources of southern pine seed. Subcommittee on Geographic Source of Seed, Philip C. Wakeley, Chairman. Processed. Southern Forest Experiment Station, New Orleans, La. Sept. 12, 1952.

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SUGGESTED PROJECTS IN THE GENETIC IMPROVEMENT OF SOUTHERN FOREST TREES

by

The Committee on Southern Forest Tree Improvement

INTRODUCTION

At the close of a South-wide conference on forest genetics held in January 1951, a standing committee representing State, federal, industrial, and educational forestry groups was appointed to foster and encourage tree improvement work in the South. This Committee on Southern Forest Tree Improvement has set up the following purposes to guide its work:

(1) To advise and assist those interested in the improvement of southern forest trees in arranging and conducting research and development programs.

(2) To provide a clearing house for forest tree improvement information.

(3) To provide for or assist in the coordination of a South-wide program of tree improvement research and development.

(4) To foster and encourage the advancement of knowledge of southern tree genetics.

The "how" and "what" of tree improvement work have been major concerns of the committee since its inception. The "how" has been approached by the preparation of guideline publications intended to summarize the best current recommendations or methodology in seed-source testing, selection of superior trees, progeny testing, and the application of genetics to seed collection. The guides published to date are listed inside the front cover.

The present publication attempts to tell the "what" of tree improvement research. It is directed to those who can help in a South-wide advance on the broad front of forest genetics and who want suggestions on what to do. For this purpose, the committee has compiled an inventory of the many studies that await attention.

The committee has not attempted to present a completely organized program with priorities and time schedules. The work selected by any

particular group necessarily depends on the local forest problem, the objective of the organization, and the money and skills available to it.

On the other hand, the committee does assist in coordination of programs to the extent feasible. Particular attention is called to the committee's "Directory of Forest Genetics Activities in the South," which should be used in conjunction with this list of needed projects. The directory tells who is doing what, and also lists the arboretum materials available throughout the South. Those interested in a given field of genetics research are encouraged to keep in touch with others who are shown by the directory to be working on the same species or problem.

The committee also serves as a clearing house for information through its semi-annual newsletter, its general meetings, its committee meetings, and its four subject-matter subcommittees on the following subjects:

Geographic source of seed
Genetic control of seed
Selection and breeding
Progeny testing

The committee is also glad to offer advice to individuals or groups as to the particular types of tree improvement work that will best meet their needs.

The remainder of this report is devoted to a list of projects or studies needed in the several major phases of southern forest tree improvement

SUGGESTED PROJECTS IN THE APPLICATION OF GENETICS TO THE COLLECTION OF SEED FOR PLANTING

1. Definition of an acceptable tree suitable for seed production for different species, and possibly for specific uses.

2. Relation of average annual seed yield to age, site, stand condition, past cone-bearing history, etc., for different species, to show seed producing capacity of seed orchards.

3. Stimulation of seed production by means of fertilization, release, wounding, banding, and other treatments.

4. Research on the relation of drought, insects, and other factors to pollen, cone, and seed losses in southern pines.

5. Research on causes of low germination of apparently viable seed.

6. Seed-testing laboratory for service testing.

7. Techniques for mass storage of seed collected in abundant seed years.

8. Development of equipment for large-scale seed collection from standing trees.

9. Research on the inheritance of seed production.

SUGGESTED PROJECTS IN GEOGRAPHIC SOURCE OF SEED FOR FOREST PLANTING

1. Restricted tests of geographic source of seed within an agency's seed collection territory (for example, a State), as outlined in the committee's publication "Standardized Working Plan for Local Tests of Seed Source."

2. Participation in region-wide cooperative studies of seed source, such as those initiated under the sponsorship of the committee in 1951. See "Working Plan for Cooperative Study of Geographic Sources of Southern Pine Seed," prepared under the committee's sponsorship.

3. Basic studies of the phenological and physiological data associated with geographic seed source. Examples are dates of pollination, onset of growth, termination of growth, frost resistance, and response to day length of different geographic strains, both in seed source plantations and in native strains.

4. Relation of geographic seed source to disease resistance and to wood properties.

5. Studies of the relative effect of environment (climate, soil, etc.) and of heredity (local breeding populations, migration paths) as determinants of seed collection areas.

OBJECTIVES IN THE IMPROVEMENT OF SOUTHERN FOREST TREES THROUGH SELECTION AND BREEDING

1. Increased volume growth per acre in commercial species.

2. For particular purposes, develop strains of pine or hardwoods having wood characteristics desired, such as:

   a. High density and strength
   b. Low density and ease of working
   c. Desirable texture
   d. Long fibers
   e. Straight grain and low fibril angle
   f. Small knots
   g. Desirable sapwood-heartwood ratio
   h. Desirable content of extractives in the wood

3. Resistance to important diseases:

   a. Fusiform rust canker in slash and loblolly pine
   b. Brown-spot in longleaf pine
   c. Littleleaf in shortleaf and loblolly pine
   d. Fomes annosus root rot in redcedar, etc.
   e. Blister rust in white pine
   f. Oak wilt, heartrot, etc., in hardwoods

4. Resistance to insect pests:

   a. Bark beetles in all southern pines
   b. Nantucket pine tip moth in loblolly pine and shortleaf pine
   c. White pine weevil in white pine

5. Increased yields of high-quality naval stores products from slash and longleaf pine.

6. Tree varieties with high resistance to drought for planting on dry sites, especially longleaf pine and other species that grow naturally on such sites.

7. Strains of longleaf pine that make rapid initial height growth in the seedling stage.

8. Strains of forest trees that permit greater utilization of the stem. These strains in all important species may have shorter crowns, shorter branches, less stem taper, and accelerated natural pruning.

9. Hardwoods, such as yellow-poplar and white oak that do not have epicormic sprouts.

10. Varieties of yellow-poplar, maple, black cherry, walnut, sweetgum, etc., that have figured wood.

11. Black walnut that produces nuts of superior quality and at the same time high-quality wood in planted stands.

12. Sweetgum that has straight grain rather than interlocked grain, for ease in drying and working.

13. Redcedar that has high vigor, desirable characteristics for use as Christmas trees and other products.

14. Black locust with good form, high heartwood percent, and fast growth.

15. Virginia pine with straight stems, small stem taper, and better natural pruning ability.

16. White oak, red oak, ash, hickory, yellow-poplar, and other hardwoods that have high growth rate yet produce wood suitable for various products. This may require higher density, lower density, greater strength or other characteristics, depending upon use for products such as veneer, lumber, handles, etc.

17. Dense-crowned, rapid-growing firs, cedars, or other species that have attractive foliage, color, and other desirable characteristics for Christmas trees.

18. Polyploid or mutant forms of important hardwoods species that may have the optimum chromosomal complement for vigor, wood quality, and resistance to pests.

19. White pine that prunes itself well naturally.

20. Chestnut that is blight-resistant and that is a timber-type tree, suitable for forest planting sites.

SUPPORTING STUDIES NEEDED IN TECHNIQUES AND BASIC ASPECTS OF FOREST GENETICS

Selection

1. Develop techniques of selection:

   a. Determine the range of inherent variation within species with regard to tree quality for timber products (logs, poles, piling, ties, lumber, veneer, etc.), derived products (pulp, cellulose, lignin, essential oils, etc.), oleoresin, and edible fruit; also with regard to resistance to drought, insects, fungi, viruses, extremes of heat or cold, and mechanical damage from ice or snow. Determine standard deviation for each trait and the correlation between pairs of the more economically important traits.

   b. Conduct surveys for phenotypically superior trees and prepare catalogues to make them available to foresters and tree breeders.

   c. Determine intraspecific taxonomic variation in important species. This will require cooperation of taxonomists to re-analyze the status of species, varieties, forms, races, and strains.

   d. Incorporate knowledge obtained from studies in mode of inheritance into plans for selecting superior phenotypes in wild populations. This will require knowledge of the economic value of important characters and the degree of genetic control. The data will be used in writing specifications for phenotypically superior trees in surveys for breeding stock.

   e. Determine which methods of selection, such as the total score method, tandem method, or others used by plant and animal breeders, are suitable for use in breeding plans for forest trees.

2. Determine correlation between juvenile and adult characters or those of intermediate ages as a basis for selection in nursery beds or evaluation of hybrids at a very young age.

3. Determine the place of mass selection in silvicultural practices for major species. Results of these studies should guide selection of crop trees and seed trees when intermediate and final cuts are made. Criteria for judging the inherent value of standing trees will be needed.

4. Selection of phenotypes for specific purposes. It is probable that many aberrant forms of forest trees will be noted in surveys for phenotypically elite trees for forestry purposes. Some of the aberrant forms may have value as specimen trees or for landscaping. Others, especially mutants, may have value in cytological studies.

Anatomical Studies

1. Determine effect of variations in structural features (width of rings, proportions of springwood to summerwood, fiber length, and fibril angle in cell walls) on important properties of density, strength, shrinkage, and pulping properties of wood.

2. Develop practical methods for selecting trees with superior wood properties on the basis of the related anatomical features. This involves sorting out the purely environmental from the genetic influences on the above-named anatomical characters, so that inherently superior trees can be identified in the field.

Breeding

1. Learn mode of inheritance of various characters:

   a. Determine compatibilities for crossing within species of softwoods and hardwoods.

   b. Determine relative importance of chromosomal and cytoplasmic inheritance of morphological and physiological characters of economic importance.

   c. Determine Mendelian ratios for inheritance of vegetative vigor, tree form, crown width, pruning ability, resistance to pests, and other characters of economic importance. This

includes studies of dominance or recessiveness of important characters and studies of number of genes involved in inheritance of characters. The genetic correlation between pairs of traits should be determined. Breeding material for such studies may be obtained from studies of natural variation and surveys for phenotypically superior trees.

d. Determine incidence of hybrid vigor in crosses within and between important species.

e. For major species determine fertility of the seed and vigor of offspring after selfing. Self-incompatible species will require cross pollination; self-compatible species may be selfed or inbred. Selfing is a valuable technique for increasing genetic uniformity.

2. Develop methods for obtaining combinations of desirable characters in hybrids:

a. From the studies of mode of inheritance of characters determine effectiveness of cross-pollination and inbreeding to obtain combinations of valuable characters in the first generation.

b. Develop breeding plans for a series of crosses and back crosses suitable for use with forest trees. This will require modification of conventional methods used in breeding annual crops, fruit trees, and farm animals. With a knowledge of inheritance of characters in trees, it should be possible to plan a series of controlled crosses to combine valuable genes into superior gene complexes.

3. Cytological studies:

a. Determine chromosome number of tree species.

b. Determine incidence of naturally occurring polyploid individuals or races; also other types of mutants, such as amphidiploids and aneuploids. This can be done in conjunction with studies of intraspecific taxonomic variations.

c. Determine if chromosome pairing is normal in hybrids. This has a bearing on some types of sterility and is therefore important in breeding programs.

d. Determine optimum number of chromosomal sets for maximum vegetative vigor, particularly in hardwoods where some polyploids are more vigorous than are diploids. This also has

importance in breeding softwoods, where polyploids may be less vigorous than diploids and would have negative selection value.

e. Develop methods for inducing mutations, particularly polyploids, to develop new tree types and permit cross-breeding of plants that have different numbers of chromosomes so that they will produce fertile offspring.

4. Explore genus Pinus and genera of important hardwoods for breeding material:

a. Determine species mostly likely to be adapted to climatic conditions in the South.

b. Establish observation plots of selected introduced species to determine vigor, tree form, and resistance to pests under typical growing conditions in the South. These tests should be made in each climatic zone and physiographic region.

c. Analyze characteristics of important species of softwoods and hardwoods with the purpose of preparing breeding plans to obtain in hybrids superior combinations of traits such as vigor, tree form, and resistance to pests.

Methods for Control of Flowering and Fruiting

1. Develop methods for inducing flowering in very young trees to reduce the time required for controlled breeding several generations of trees. Techniques such as freezing, top grafting, artificial illumination, ringing, and strangulation may be tried. Also, selection of early flowering strains may be possible.

2. Perfect methods of stimulating flowering or fruiting in large trees, to aid in controlled breeding or in mass production of seed of selected trees and strains.

3. Develop methods of pruning and culture for mass production of seed in planted seed orchards. This might require methods of crown pruning to keep the trees small in size but capable of producing a large number of flowers. Such techniques would be useful in large-scale controlled breeding or in production of seed of superior strain.

4. Develop methods for controlled mass pollination in production of seed of superior strains. New techniques may be needed in seed orchard management to insure cross-pollination of certain strains to avoid possible undesirable effects of inbreeding. Control of pollen production would be an important aid in breeding monoecious plants because it would make emasculation unnecessary.

Methods of Vegetative Propagation

1. Develop methods of propagating--by grafts or cuttings--the important tree species. This includes grafting material from mature trees to seedling stocks and material from seedlings or young trees to branches of mature trees.

2. Investigate stock-scion relationships in forest trees to permit use of dwarfing or stimulating effects for special purposes in production of breeding stock, development of seed orchards, or for field planting. Field planting of grafted stock or cuttings may be feasible with figured strains of walnut, poplar, maple, and other species.

3. Determine to what extent ability of cuttings to root is genetically determined. If strongly controlled in certain species, rooting ability should be a character to consider in selection.

4. Perfect techniques for using vegetatively propagated material to estimate the genotype of selected phenotypes.

Equipment for Tree Improvement Work

1. Controlled breeding:

   a. Perfect more efficient equipment for collecting pollen, extracting pollen, bagging flowers, pollinating flowers, protecting cones from pests, and marking the flowers that have been pollinated.

   b. Develop new equipment or adapt existing equipment for climbing mature trees.

   c. Develop methods and equipment for storing and transporting pollen of all important genera.

2. Seed collection:

a. Develop equipment for collecting cones from mature trees.

b. Develop methods of seed extraction and seed cleaning suitable for small amounts of fruit.

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INTERCEPTION OF RAINFALL IN A YOUNG LOBLOLLY PINE PLANTATION

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INTERCEPTION OF RAINFALL IN A YOUNG LOBLOLLY PINE PLANTATION

by

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INTRODUCTION

Those who have sought refuge during a storm have found a tree to be an effective umbrella for a light shower but leaky in a heavy rain. Even so, it is usually possible to stay slightly more dry under forest canopy than in the open. That is because a portion of the rain is stored on leaves and branches and eventually evaporated back to the air. The term interception is used for both the process and the amount of water thus dissipated. If one watches the rain drops, he can see how the process works. The first raindrops that strike the foliage spatter out, wetting the leaf surface. Finally the leaves are thoroughly wetted and water begins to drip off to the ground. Of course, some raindrops find openings in the tree crown and fall through directly to the ground. A part of the rain falling onto leaves and twigs flows from them to larger branches and finally runs down the trunk to the ground. The portion which is led to the ground down the stem is called stemflow, while that falling directly to the ground or dripping from twigs and leaves is called throughfall because it passes through the canopy. The sum of throughfall and stemflow or the total rain reaching the ground beneath a plant canopy is net rainfall.

Because there is a difference in density and arrangement of foliage for different tree species, much speculation and some measurements have been used to compare the net rainfall beneath stands of various tree species.[1/] In connection, with a study of soil moisture on the Calhoun Experimental Forest[2/] it was necessary to measure the net rainfall under a young loblolly pine plantation. The results of that study are reported here.

1/ For a discussion of interception and literature references, the reader is referred to: Kittredge, J., Forest Influences, McGraw-Hill Book Co., New York, 1948.

2/ Located 7 miles southwest of Union, S. C.

DESCRIPTION OF THE STAND

The trees were planted as one-year seedlings in February 1941. The intended spacing between trees was 6 feet each way but the actual spacing was about 6.5 feet. In the period May 1950 to March 1951 during which observations were made, the trees were in their tenth growing season after planting. There were an average of 760 trees per acre with an average d.b.h. of 5.3 inches and height of 31 feet. A few trees were as large as 7 inches in diameter and 35 feet in height. The basal area per acre was 103.3 square feet. On 10 sample trees, the average length of stem bearing live branches was 13.6 feet, which was 44 percent of total height. Although the canopy was rather dense in appearance, the total projected crown area based on the sample trees was 25,300 square feet per acre, indicating that only 58 percent of the ground surface in the plantation was directly below tree crowns.

HOW MEASUREMENTS WERE MADE

Throughfall

Two rain gages were used beneath the canopy to measure throughfall and two in nearby openings to determine rain in the open. Figure 1 shows their general location. The four lines along which rain gages under the canopy were moved were laid off at right angles to the planting rows. On each line, 10 stakes were set at 4-foot intervals (fig. 2). Rain gages were moved from one stake position to another after each storm and the cycle was repeated on a line until four storms were sampled at each position. The rain gages were on lines 1 and 2 from May 3 to August 23, 1950 and on lines 3 and 4 from August 24, 1950 to March 30, 1951.

Statistically, it would have been better to randomize the rain gage positions. The systematic arrangement used insured sampling a wide range of conditions and gave a good estimate of average interception in the plantation but may invalidate statistical analyses based on random distribution. In spite of this objection, the comparisons between lines and positions were made by ordinary covariance methods. There was no advantage in the resampling of positions on a line and it would have been better to occupy completely randomized locations; truly random location is recommended for future studies.

The rain gages used are similar to the conventional non-recording Weather Bureau rain gage except that they are only 10 inches high and the inner cylinder overflows into the large container after 0.5 inch of rain.[3/] These gages can be set directly upon the ground without external support, which made it easy to move them to new locations.

3/ The rain gages were designed by the Division of Fire Research, Southeastern Forest Experiment Station.

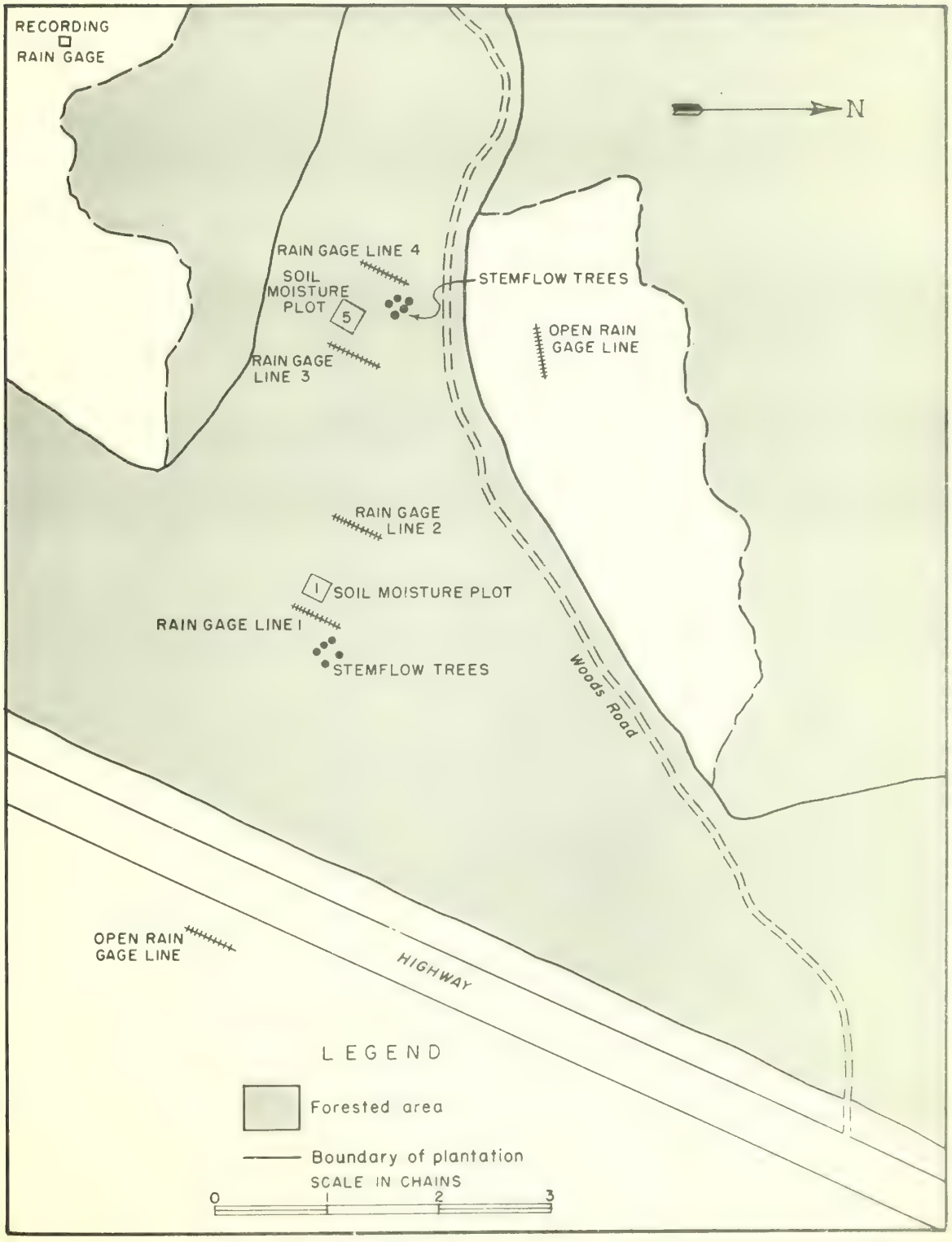

Figure 1.--Location of rain gages and stemflow trees in the loblolly pine plantation.

Rainfall in Open

As shown by figure 1, the open rain gages were in clearings only a short distance from the plantation. In addition, a recording rain gage of the regular precipitation network of the experimental forest was also nearby. The record for all gages in the open was remarkably similar, indicating that rainfall was uniform over the observation area.

Figure 2.--Measurement of throughfall. Numbered stakes mark sampling positions. The undercanopy rain gages are set directly upon the ground. Note the upthrust branches of the young loblolly, believed to cause the high proportion of stemflow.

Stemflow

Stemflow was measured on 10 trees. They were chosen by locating a point at random near the locations on which throughfall was measured. The nearest five trees to the point were equipped for stemflow measurements. Stemflow was diverted from the tree trunk by a spiral tin gutter nailed to the tree and sealed by asphatum cement. Bark was smoothed for about 2 feet above the gutter. The gutters were made narrow to minimize the amount of rain falling directly into them. Water was lead by a rubber hose to 5-gallon cans. From two to five cans were connected together to provide the capacity needed for a given tree. After each storm, the cans were weighed to the nearest 2 ounce on a small platform balance (fig. 3). This was convenient and furnished a high order of accuracy. There was some difficulty in keeping hoses free from bark, pitch and trash, and continual vigilance was necessary to keep them open. Stemflow was measured between August 12 and December 10, 1950, and good records were obtained for 17 storms during that time.

Figure 3.--Weighing the collection cans to determine amount of stemflow.

A comparison of stemflow in relation to rainfall was made for the two groups of five trees and there was no significant difference between them. It was then assumed that any other group of five trees in the stand would give similar results, and measurements for the 10 trees were combined to give total stemflow in pounds per storm. The total stemflow for these trees in pounds was multiplied by 76 (there were 760 trees per acre) and was converted to inches depth to express it in the same unit as rainfall is measured.

RESULTS

Both throughfall and stemflow were found to be linear functions of the amount of rain per storm (fig. 4). Throughfall did not occur when rainfall was 0.02 inch or less. The equation for throughfall is:

$$\text{Throughfall} = .732(\text{Rain in open}) - .016 \quad \ldots\ldots\ldots \quad 1.$$

Stemflow was insignificant for storms less than 0.10 inch. For these small storms, net rainfall can be obtained from the throughfall equation. The equation for stemflow is:

$$\text{Stemflow} = .222(\text{Rain in open}) - .018 \quad \ldots\ldots\ldots \quad 2.$$

The total rainfall reaching the ground under the trees for storms 0.10 inch and larger can be obtained by solving both equations 1 and 2 and adding the results. However, it is more convenient to estimate net rainfall by the equation for net rainfall given below. This equation applies only to storms of 0.10 inch or larger.

$$\text{Net rainfall} = .954(\text{Rain in open}) - .034 \quad \ldots\ldots\ldots \quad 3.$$

The error of estimate for the throughfall equation is 0.11 inch for an individual position within the stand with a mean storm size of 0.45 inch. The correlation coefficient is 0.92. The standard error for stemflow is .008 inch for a mean storm size of 0.80 inch. The correlation coefficient for stemflow is 0.99.

The relationship of throughfall to rain in the open was similar on each of the four under-canopy rain gage lines, and regressions for each line were not significantly different. This indicates that throughfall is essentially similar throughout the plantation. A test was made for differences associated with season or time by computing regressions for individual cycles on the lines. Difference in cycles was not significant and it may be inferred that throughfall is not influenced by season. Measurements were classified into the following storm-size classes; .01-.10, .11-30, .31-.57, .57-1.00, and above 1.00 inch. Regressions for these individual groups did not differ significantly.

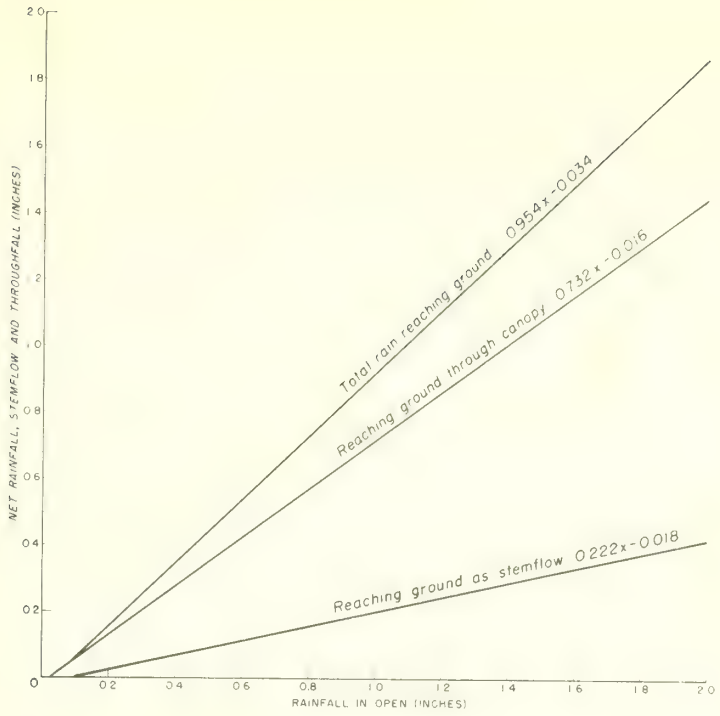

Figure 4.--Total net rainfall, throughfall and stemflow as compared with rain in open. Loblolly pine 10 years after planting.

These comparisons indicate that throughfall can be estimated with confidence from rain in the open without additional refinement.

An effort was made to relate stemflow to tree characteristics. There was a tendency for stemflow to be larger for trees taller than their neighbors or with more live branches in the crown. However, there was so little difference in the appearance of individual trees that classification appeared to serve no practical purpose.

Interception has been frequently expressed as a percentage of total rainfall. To facilitate comparison with such information, figures 5 and 6 were prepared to show the percentage of canopy interception, stemflow, and their sum in relation to storm size.

Actually the amount intercepted from light showers is of little significance because even if it did reach the ground it would have neglible effect on soil moisture. In fact, during the growing season, a few hundredths of an inch on the foliage is more helpful to the trees than the same amount applied to the soil. Wetting the leaves serves to reduce transpiration rates, and during periods of soil moisture stress this may be of considerable benefit.

For periods of time such as months, seasons, or years the amount and percentage of rainfall that reaches the ground can be expected to show considerable variation. Less rainfall will reach the ground in a period when storms are small as compared with similar time intervals with the same total rainfall but received in larger storms. For example, in a single storm of 1.00 inch in the open, 0.92 will reach the ground

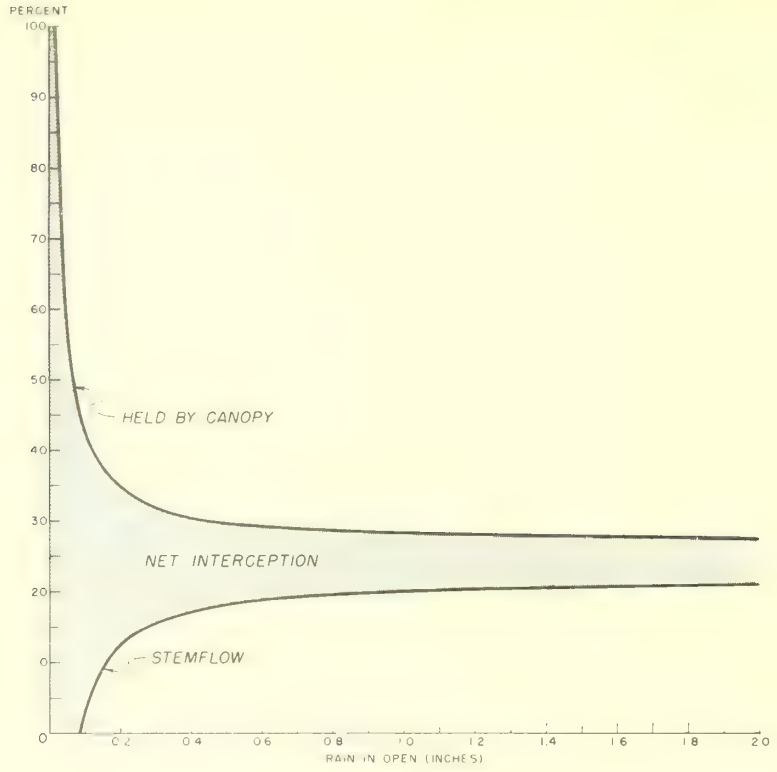

Figure 5.--Throughfall and stemflow as a percentage of rain in the open.

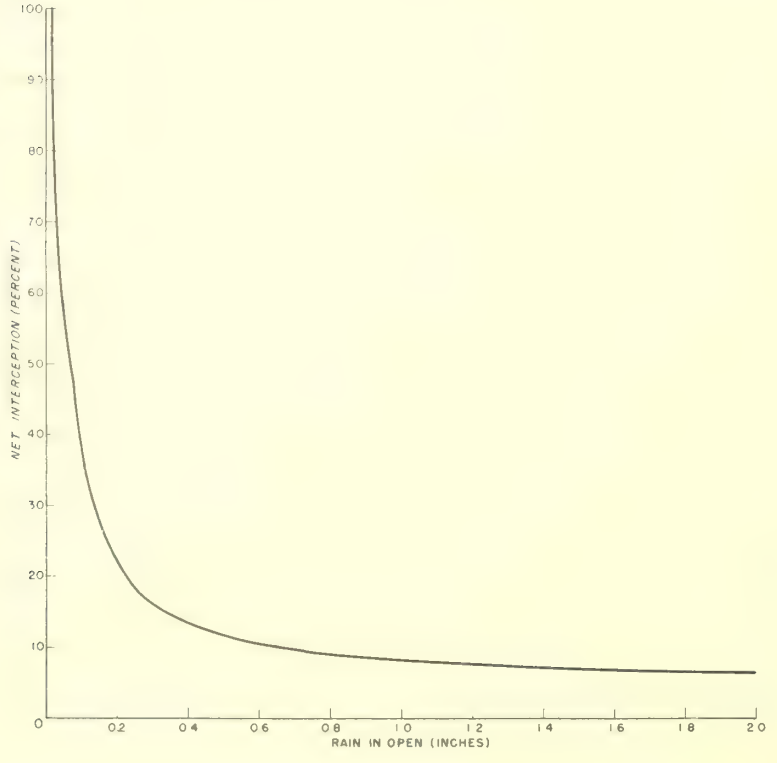

Figure 6.--Net interception as a percentage of rainfall in the open.

below the trees, but when five storms of 0.20 inch occur the total net rain under the tree crown is only 0.78 inch. Table 1 gives the estimated net rainfall under the loblolly plantation for two years differing considerably in total rainfall. Although shown as monthly totals, net rainfall was actually estimated for each storm.

Table 1.--Estimated net rainfall under 10-year-old loblolly pine, with rainfall as received in 1948-49 and 1949-50 at Union, S.C.

Period	1948-49			1949-50		
	Rainfall		Reaching ground under trees	Rainfall		Reaching ground under trees
	In open	Under trees		In open	Under trees	
	Inches	Inches	Percent	Inches	Inches	Percent
October	1.54	1.21	79	2.32	1.93	83
November	10.09	9.11	90	1.61	1.39	86
December	4.42	3.88	88	2.30	1.85	80
Fall total	16.05	14.20	88	6.23	5.17	83
January	4.43	3.96	90	2.51	2.08	83
February	5.58	4.98	89	1.50	1.19	79
March	1.89	1.53	81	3.96	3.35	85
Winter total	11.90	10.47	88	7.97	6.62	83
April	5.58	4.76	85	1.49	1.28	86
May	3.01	2.57	86	4.15	3.66	88
June	2.15	1.84	86	2.82	2.28	81
Spring total	10.74	9.17	85	8.46	7.22	85
July	3.47	2.89	83	3.49	2.86	82
August	12.67	11.68	92	3.10	2.69	87
September	2.43	2.01	83	3.07	2.71	88
Summer total	18.57	16.58	89	9.66	8.26	[illegible]
Annual total	57.26	50.42	88	32.32	27.27	84

While net rainfall per month is only 80 to 90 percent of rain in the open, it is believed the redistribution of rainfall as a result of stemflow is of more importance. Each of the young pines is a rainfall concentrator receiving rain over its crown spread and funneling a large part of it down the trunk to the ground. A large volume of water is thus accumulated and applied to a narrow band around the trunk. In this plantation, for example, during a 1-inch rain the average tree leads an average of 8 gallons to the ground down the stem. To illustrate the amount of stemflow, table 2 gives the estimated stemflow as inches per acre and as gallons per tree by months for the years 1948-49 and 1949-50.

Table 2.--Estimated stemflow per acre and per tree, with rainfall as received in 1948-49 and 1949-50 for 10-year-old loblolly pine plantation

Period	1948-49			1949-50		
	Rain in open	Stemflow		Rain in open	Stemflow	
		Per acre	Per tree		Per acre	Per tree
	Inches	Inches	Gallons	Inches	Inches	Gallons
October	1.54	.23	8	2.32	.36	13
November	10.09	1.94	69	1.61	.27	10
December	4.42	.81	29	2.30	.31	11
Fall total	16.05	2.98	106	6.23	.94	34
January	4.43	.82	29	2.51	.38	14
February	5.58	1.04	37	1.50	.19	7
March	1.89	.26	9	3.96	.60	21
Winter total	11.90	2.12	75	7.97	1.17	42
April	5.58	.97	35	1.49	.26	9
May	3.01	.46	16	4.15	.75	27
June	2.15	.38	14	2.82	.41	15
Spring total	10.74	1.81	65	8.46	1.42	51
July	3.47	.36	13	3.49	.49	18
August	12.67	2.56	91	3.10	.74	26
September	2.43	.36	13	3.07	.53	19
Summer total	18.57	3.28	117	9.66	1.76	63
Annual total	57.26	10.19	363	32.32	5.29	190

The volume of stemflow is of benefit to the tree because it is added to the soil where it is readily available to roots. Moreover, it is frequently of sufficient quantity to cause accretion of moisture to considerable depth in the soil. The area at the tree base often receives a thorough soaking when the space between the trees is only dampened. As a result, moisture recharge may take place to considerable depth near the trees when only the surface horizon in the interspaces receives moisture. Neglect of this unequal application of water would cause an underestimate of the water available to the trees and of the moisture added to subsoil horizons.

Stemflow water is added to the ground where conditions are favorable for it to be rapidly absorbed. Around the base of pines there is normally an accumulation of needles, bark and other debris (fig. 7) which provides a favorable condition for water entry. Deep penetration of water is also facilitated by the passageways made by roots and associated organisms. As planted trees develop on old fields, conditions causing rapid infiltration of water are created first near the base of trees. Thus the concentration of a sizeable portion of rainfall in that zone by stemflow aids in bringing about a reduction in surface runoff at an earlier stage of plantation development than would be the case if rain reached the ground more evenly distributed. If forest fires remove the debris around the tree bases, an unfavorable condition is created for water entry. Examination of the area around the stems after a fire frequently shows a ring of bare, crusted soil washed clean of charcoal by stemflow water (fig. 8).

Figure 7.--The accumulation of needles, bark, and debris at the base of trees creates favorable conditions for the rapid infiltration of water flowing down tree trunks.

Figure 8.--Fire removes the protective litter from the ground at the base of trees. Stemflow water then frequently becomes surface runoff as shown above, where the soil in a ring around the trees has been washed free of charcoal and is packed and bare.

The quantity of stemflow reported here for young loblolly is at the upper range of stemflow values reported in the literature for various species. The crown form is the best explanation for the large volume of stemflow. Young loblolly pines have sharply uptnrust branches terminated by a cluster of long needles. This arrangement forms an efficient system for leading water to the trunk. The same branch arrangement and even longer needles characterize young slash and longleaf pines. Therefore, it is expected that stemflow for those species is very likely comparable to loblolly pine. No information is available to estimate stemflow for older loblolly pine.

CONCLUSIONS

The reduction in net rainfall due to interception in a plantation of 10-year-old loblolly pine is less than was expected. On an annual basis, net rainfall will average about 86 percent of rain in the open. Only a small part of heavy rains is intercepted. Reduction in surface runoff caused by the development of loblolly pine on old fields is not due to interception but to improved conditions for intake of water into the soil. A sizeable proportion of rainfall does reach the soil as stemflow and this aids in reducing runoff by concentrating water where conditions are ideal for water entry. Stemflow also makes more water available to the trees than would be the case if rainfall reached the soil with uniform distribution.

It is not known whether this high proportion of stemflow is maintained as loblolly increases in height and age. In any studies of net rainfall under stands of the Southern pines, stemflow is a factor which must be considered.

SUMMARY

In a 10-year-old planting of loblolly pine near Union, S. C., the amount of rainfall reaching the ground by passing through the tree crowns and as flow down the tree trunks was measured. Regression equations for estimating the net rainfall, throughfall, and stemflow on the basis of rainfall in the open were determined. Net rainfall under the trees was found to average about 86 percent of rain in the open. A considerable proportion of rainfall reaches the ground as flow down the stems. The redistribution of rainfall due to this concentration of rain water at the base of trees is believed to be significant to tree growth and soil moisture. No seasonal differences in the proportion of net rainfall were found. Results apply only to precipitation occurring as rain.

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SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina
E. L. Demmon,
Director

U. S. Department of Agriculture - Forest Service

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INTRODUCTION

The national obligation for defense and foreign aid brings a pinch on normal services of the federal government, including forest research. Inflation not compensated by appropriations has meant a steady decline for several years in the Station's research efforts. While appropriations have remained about the same, the value of the research dollar has shrunk greatly. This has been offset only in part by an increase in cooperative research funds.

Pressing from the other direction is an increasing need for more research to guide the rapid expansion of the South's tremendous forest enterprise. More accurate information on the location and extent of timber supplies is in great demand. The increase in intensive forest management practices in the Southeast is crowding the rate at which such practices can be assisted by research. Information is needed now on forest genetics, on forest regeneration of dry sandy areas, on reclamation and management of poorly drained areas, and on utilization of less valuable and little-used species--problems that have been largely passed over in earlier research because of lack of "consumer" interest. There is no lack of such interest now.

The shrinkage of the research dollar in the face of increasing needs for information demands a solution. It lies in the joint effort of all forestry groups in the region working together to meet the research needs. Research by States, industries, and forestry schools got a late start in the Southeast, but is coming along rapidly. It is now a major part of the whole research pattern.

In view of these trends the Station has increased its efforts to coordinate its program with that of other groups. It has enlisted the help of others where such help is available, as attested by this report. It has initiated grants-in-aid to others in the research field who are better equipped to solve particular problems. It has made increasing use of local advisory committees to assure that its studies are best geared to the needs of the local people and to the programs of cooperating agencies.

The Station will continue to foster this cooperative approach toward common problems. It will continue to concentrate on certain long-range, fundamental, or regional jobs which are by nature a federal responsibility. It will also work side by side with all those in the Southeast who can help in developing the "know-how" to best promote the future progress of the forest economy of this region.

FOREST MANAGEMENT

Forest management research in the Southeast is confronted with many challenging problems in the growth and harvesting of timber crops. Increasing population pressure and maintenance of a multi-billion dollar forest industry require that idle lands be reforested, partially stocked woodlands raised to full productivity, and well stocked stands perpetuated. These problems are being attacked by the Station in cooperation with the states, with industry, and others, at several Research Centers located in each of the major forest areas of the Southeast. The needed information is obtained in intensive project studies, through trials of different management systems on 30- to 100-acre compartments on experimental forests, and by pilot-plant operations on a larger scale.

REGENERATION

Starting a new forest crop is probably the most important forest management activity. Failure to promptly secure a well stocked, evenly distributed stand of the best species for a particular site penalizes the landowner throughout the next rotation by loss of potential volume growth. Furthermore, any subsequent effort he makes to bring the stand up to full productivity requires an additional outlay of labor and money. Consequently, the Station has devoted as much attention to solution of the regeneration problem as to any phase of forest management. Some of these experiments have begun to pay handsome dividends.

Loblolly Pine

Considerable information was obtained prior to 1952 about seed production, seed dispersal, seedbed requirements, and hardwood control problems involved in the regeneration of loblolly pine. For example, good seed crops occur at irregular intervals of from 1 to 5 years. The expected size of the next seed crop can be predicted a year in advance of seedfall by determining the ratio between immature conelets and mature cones of the last crop. Second-growth loblolly pines in pulpwood-age stands, usually too immature to be considered for seed production, can be stimulated to produce large seed crops by completely releasing each chosen seed tree from competition by its neighbors. This should be done 3 years in advance of the final harvest date. In mature stands, the possibilities for abundant seedfall in the first season following harvest can be increased by careful selection of the trees to be left. Trees 12 inches in diameter or larger with a large number of old cones in sight have been found to be most prolific. During poor seed years the possibility of obtaining an adequate stand of reproduction can be greatly enhanced by a type of seedbed preparation that will expose mineral soil. Both prescribed burning and mechanical scarification with disks or bulldozers are satisfactory. These treatments also reduce hardwood competition, a major problem in itself on moist, fertile sites. Much of the research in hardwood control has been with chemical silvicides, the most promising being 2,4-D, ammonium sulfamate ("Ammate"), and 2,4,5-T. The extent of public

interest in silvicides is indicated by requests for more than 7,000 copies of Station Paper No. 10, "The Use of Chemicals to Control Inferior Trees in the Management of Loblolly Pine," issued in September 1951.

During 1952 much additional knowledge has been obtained from current studies; some of the more important findings are listed here.

Intensive tests of seed-tree stimulation by application of commercial fertilizer to the soil around each tree revealed a significant increase in cone production of 25-year-old trees. However, 40-year-old trees failed to respond satisfactorily, perhaps because of insufficient treatment or prior release. Although fertilizer treatments are too expensive for use in seed-tree cuttings, they could be a profitable aid in seed orchard culture.

In southeastern Virginia, results of earlier research in loblolly pine seed and seedbed requirements received practical application on private land some distance from the Bigwoods Experimental Forest. The pulpwood-size timber on this tract was removed in a partial cut, the intent being to remove the larger trees later if sufficient reproduction was obtained. Most of the ground not scarified during log skidding was disked so that 64 percent of the seedbed was disturbed soil, 16 percent was covered with slash concentrations, and 20 percent remained untouched. Seed production by the residual stand was measured with seed traps scattered about the tract. The statistics on seedbed condition and seed supply were then converted to the expected number of seedlings and percent stocking by use of information in Station Paper No. 8, "Seed and Seedbed Requirements to Regenerate Loblolly Pine." The final stand of seedlings was well within the predicted range. Thus forest industry is armed with one more tool for intensive management.

Seed crop forecasting also received commercial application in the Coastal Plain of Virginia and North Carolina. A bumper crop is forecast for 1953, although indications are that it will be larger near the coast than inland.

Because of the build-up of hardwood competition after seed-tree or strip clear cutting in loblolly pine, prompt establishment of reproduction has been recognized as an obvious requirement for success. Now it has been found that in addition to hardwood encroachment, delayed seeding of pines may also be responsible for stocking failures. An analysis of thirteen 40-acre managed compartments, cut during the years 1946 through 1950, disclosed that favorable seedbed conditions for loblolly pine disappear within 3 years after logging. Therefore a planned regeneration schedule should be a part of any harvest cutting program. Partial cuts should be scheduled for the years when seed crops are poor and cutting for regeneration concentrated in good seed years.

Sometimes, wet weather in late summer and early fall delays prescribed burning for seedbed preparation and hardwood control. However, winter fires in loblolly pine stands consume most of the seed that may be on the ground. Furthermore, few seeds are disseminated after February 1

from cones still on the trees, so restocking of winter burns probably will be delayed an additional year.

How and when to remove seed trees so as to minimize damage to reproduction received attention in eastern North Carolina. The tract contained an average of six good-sized seed trees per acre which were removed in the fall after their seeds had been disseminated. By locating landings in advance, encouraging cutters to fell trees directly toward or away from these spots, and skidding in tree lengths, damage to reproduction was confined to 16 percent of the area, of which only one-half was damaged severely. New seedlings from the last seed crop may later germinate in the skid roads, but planting is needed on loading areas where damage was complete.

As seedling behavior partially determines the adaptability of a species to a site, information has been secured about the growth of 1-year-old sweetgum and loblolly pine seedlings in soils of three different textures and under three levels of moisture supply. Although the sweetgum seedlings produced more dry matter and developed larger root systems, the growth in length of leaders and branches was less than that of the pines under all conditions of the experiment. However, field results might differ somewhat from those obtained in this greenhouse test.

Re-establishment of Loblolly and Slash Pine

The common practice of clear cutting frequently results in obtaining scrub hardwoods instead of a new crop of pines. Understory hardwoods, ever present in the merchantable stands of the Georgia Piedmont, soon close the canopy and preclude the successful establishment of pines. Fifteen percent of the pine uplands of this region, estimated to aggregate two million acres in area, already have reverted to brush and low value hardwoods. Planting will have to be resorted to if we want to grow another crop of pine on these acres. Even so, establishment of planted pines in recently cut-over woods, in competition with understory hardwoods, will never be as successful as old field planting. Some form of pretreating the planting site may be necessary. Such a test has been made near Athens, Georgia, in cooperation with the School of Forestry, University of Georgia.

Loblolly and slash pines were planted immediately after logging on plots that received various treatments for hardwoods control. Mere cutting of understory hardwoods was of no benefit. Cutting all hardwoods over 2 inches in diameter and broadcast burning, or grubbing out the hardwood root stocks, provided 25 to 30 percent more free-growing seedlings than no treatment. For all treatments, loblolly pine displayed considerably better survival, greater height growth, and more free-growing seedlings than slash pine. The recommended commercial practice on similar sites would be chopping the brush with a tractor-drawn Marden brush cutter or broadcast burning. Hardwoods above 4 inches in diameter could be poisoned with Ammate or 2,4,5-T.

Reforestation of South Florida Slash Pine Sites

South Florida slash pine (*Pinus elliottii*, var. *densa*), a distinct botanical variety of native American slash pine, occurs on an area of approximately 1,750,000 acres in the southernmost portion of Florida. About one million acres of the type is denuded and cannot be reforested naturally for lack of an adequate seed source. Another half million acres is understocked.

This problem is the subject of cooperative research by the Collier Company, Atlantic Land and Improvement Company, Florida Forest Service, Hendry County, and the Southeastern Station. The project is still too new to permit any recommendations for reforestation, but it is known that planted seedlings succumb readily to extreme variations of flood and drought, while cotton rats have consumed much of the seed sown in direct-seeding trials.

Sand Pine Regeneration

Sustained yield management of a 210,000-acre stand of sand pine on the Ocala National Forest, having a potential annual harvest of 35,000 cords, hinges upon discovery of some harvest-cutting technique or treatment that will result in regeneration of the stand. In nature, the persistent cones on living trees open when wildfires of killing intensity sweep through the forest. If temperature and moisture conditions are favorable, a new generation is born. But foresters have not yet developed an artificial means of obtaining the same result. So far, seedbed preparation with a Marden brush cutter or heavy duty disk, in conjunction with lopping and scattering, results in the most seedlings if treatment is applied in late summer or fall about 4 to 6 weeks after harvest cutting. Seeds released at other seasons either are consumed by ants, rodents and birds, or germinate and fail to survive the hot summer months.

THINNING

More Man-hours Required to Harvest Small Trees

Silvicultural treatments sometimes need to be modified to meet economic requirements. For example, thinnings should provide an economically operable cut. A better understanding of cost factors in harvesting pulpwood from thinnings has been obtained on the Hitchiti Experimental Forest in a study of the relationship between tree size and production rate on a chain-saw operation. Cutting a cord of wood from 5-inch trees takes twice as long as from 9-inch trees. The actual man-hours per cord required to fell, limb, and buck average trees of varying diameter are shown in table 1.

These figures represent 60 percent of the total time involved. The remaining 40 percent was constant regardless of tree size and was subdivided as follows: 20 percent for walking between trees and occasional swamping, 17 percent for on-the-job equipment delays, and 3 percent for hang-ups.

Table 1.--Man-hours per cord to fell, limb, and buck pine pulpwood

D.b.h. (Inches)	Felling	Limbing and bucking	Total
	Man-hours	Man-hours	Man-hours
5	0.65	0.93	1.58
6	.44	.78	1.22
7	.33	.67	1.00
8	.28	.57	.85
9	.24	.52	.76
10	.22	.47	.69
11	.20	.44	.64
12	.19	.41	.60

Early Competition in Slash Pine Plantations

A study of slash pine seedlings planted on 6 x 6-foot and 12 x 12-foot spacings revealed significant difference in diameter growth due to competition but no marked difference in height growth. Competition in the 6 x 6-foot planting began as early as the third year after planting. At the end of 7 years slash pines in the 12 x 12-foot plantation averaged about 1 inch larger in diameter than those more closely spaced. The 6 x 6-foot spacing produced a greater total basal area, and also resulted in better natural pruning. Spacings as wide as 12 x 12 feet are not recommended generally. Nevertheless, plantation managers should be aware that competition can occur at a rather early age in close spacings of slash pine and that the maximum diameter growth of potential crop trees is not realized at these close spacings. Also, consideration must be given to costs of harvesting close-spaced trees unless provision is made for roads.

STAND IMPROVEMENT

In bygone days lumber prices were so low and utilization practices so primitive that markets could be found for only the best quality yellow-poplar, pine, and white oak. As prices rose and utilization improved, successive waves of loggers returned to high grade the forests. But always poorly formed or defective trees and those of inferior species were left behind. Thus by default millions of acres of once-productive forest land have been surrendered to inferior hardwoods.

Returning these lands to productivity is one of the major objectives of forest managers in the South today. The job is not as difficult as it seems. It can be accomplished by better utilization of inferior species, protecting valuable species as a source of seed, and eliminating hardwood competition by prescribed fire or the use of mechanical, chemical, or manual

methods. Such techniques have been the subject of numerous experiments in the loblolly pine type of the Coastal Plain.

GROWTH AND MORTALITY

Effect of Cutting Methods on Hardwood Growth

Regardless of how they are harvested, most Southern Appalachian forests come back in new growth that in time becomes merchantable. This is largely owing to a wealth of species and to favorable soil and climatic conditions for growth. But indiscriminate cutting needlessly lowers forest values and makes it harder to sustain future values. These conclusions arise from a study begun in 1930 on the Bent Creek Experimental Forest near Asheville, N. C., of a typical run-down mountain hardwood stand.

Three cutting treatments have been applied: (1) clear, (2) a flexible 14-inch diameter limit, and (3) selection for quality growth. Each method had certain advantages and disadvantages. Analysis of results 20 years later disclosed that no single treatment was best in all respects, although selection for quality gave the best all-around results. This method provided the greatest value increment, and only slightly less volume growth than the flexible diameter limit cutting. Clear cutting resulted in the greatest average annual growth of solid wood, mostly cordwood. It was too early for sawlogs--only 80 board feet per acre were produced in the 20-year study period.

Accretion in value of all wood products, expressed as an annual compound interest rate, was 0.5 percent for the uncut check, 5.0 percent for diameter limit, and 5.6 percent for selection, without taking into account the rise in timber values during the 20-year period. These results indicate that improvement cuttings, varied to fit the needs and objectives of individual landowners, can effect a tenfold increase in the annual earning power of the largest and most important forest type in the Southern Appalachians.

Response of Residual Saplings to Complete Release

Observations of clear-cut tracts on the Hitchiti Experiment Forest in central Georgia reveal that 31 percent of the residual saplings of long-suppressed shortleaf and loblolly pines died within 3 years after logging. The suppressed trees that survived showed a distinct increase in growth. A good correlation existed between diameter growth and initial crown ratio, while diameter increment was also associated with gain in crown ratio.

Effect of Winter Burning on Slash Pine Growth

In the flatwoods portion of southeast Georgia and northeast Florida, prescribed burning has become a recognized and necessary method of reducing fire hazard. This treatment enables land managers to remove the accumu-

lated growth of palmetto, gallberry, wire-grass, and leaf litter at a season when fires can be easily controlled. However, the method of burning may have a marked effect on the survival and subsequent growth of overstory trees.

Burning studies begun at the Lake City Research Center in 1944 reveal that winter headfires caused a marked reduction in subsequent height and diameter growth of slash pine, but backfires have little or no effect, providing the trees are more than 12 feet high. The tallest tree killed on plots burned by backfire was in the 8-foot height class, while headfires killed one tree 36 feet tall.

Effect of Fusiform Cankers

Six years' observation of loblolly pine trees with a diameter range of 11 to 17 inches at breast height indicates that fusiform cankers rarely weaken trees in the Santee River area enough to succumb to wind-breakage. But location of a canker within the first or second log of a tree has an important bearing on grade or yield.

FINANCIAL ASPECTS

Rules-of-thumb for Volume and Value in Pulpwood Trees

Questions about the volume and stumpage value of individual trees invariably arise during woodland operations. Usually it is inconvenient or impossible to consult a volume table for this information. The Station has developed convenient rules-of-thumb for determination of pulpwood volume and value of second-growth shortleaf and loblolly pines 8 to 13 inches in diameter. Where D is the tree diameter at breast height:

Solid volume of rough wood in cu. ft. = $4(D-6)$

Stacked volume of rough wood in cords = $\frac{4(D-6)}{100}$

Pulpwood stumpage value per tree = $\frac{4(D-6)}{100}$ x current pulpwood price per cord

Comparative Stumpage Prices

Owners of second growth pine in the Southern Piedmont ought to know whether it is more valuable for pulpwood or for saw timber since integrated sales are uncommon in that region and lively competition exists between small sawmill operators and pulpwood contractors. With the aid of Station Paper No. 16, "Comparative Stumpage Prices for Small Pine Saw Timber and Pulpwood," timber owners can determine whether prevailing market conditions make it more profitable to sell stumpage as saw timber or as pulpwood. For example, if a seller is offered $5 a cord for 8-inch trees, figure 1 indicates that he cannot afford to sell them as saw timber unless he gets $20 a thousand or more (International 1/4-inch scale). Conversely,

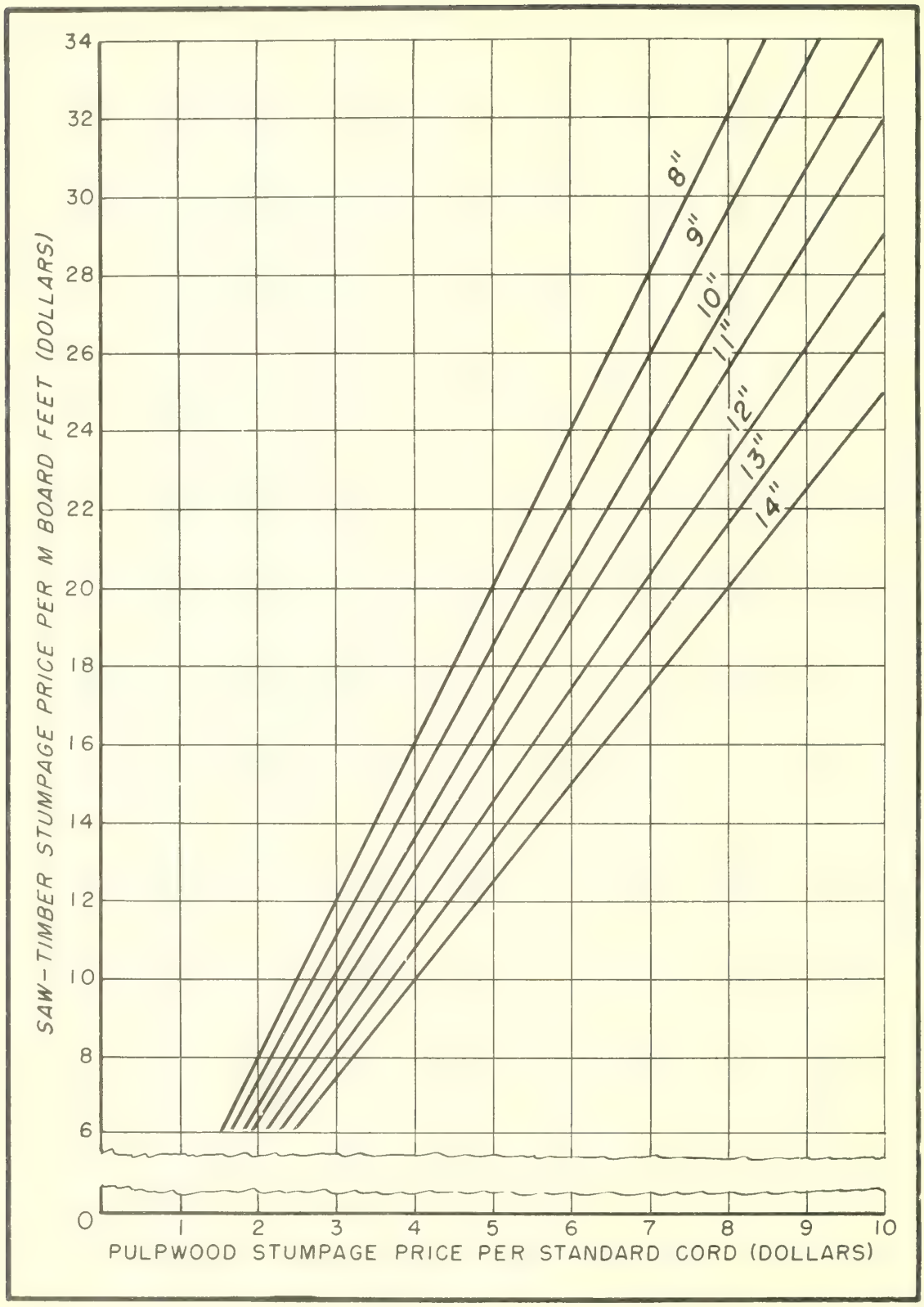

Figure 1.--Comparative stumpage prices for loblolly and shortleaf pine pulpwood and saw timber, International 1/4-inch scale, on the Hitchiti Experimental Forest. This scale most closely approximates a mill tally scale.

if he is offered $20 a thousand as saw timber for 8-inch trees, and $6 a cord as pulpwood, it will profit him most to sell as pulpwood. The figure is based on comparisons of the volume of cordwood (to a cordwood top limit) and saw timber (to a saw-timber limit) in trees of different sizes, as explained in Station Paper 16.

Timber Cutting and Skidding Costs in Southern Appalachians

Most timber operators have a fair idea of their total logging costs, but have not taken time to examine separate cost components. Consequently, they do not know where to start reducing costs when the profit margin shrinks below an acceptable limit.

The effect of tree size, species of timber, and type of equipment was studied on several typical operations within a 75-mile radius of Asheville, N. C. Felling and bucking time per M board feet was directly and closely related to tree size (fig. 2). Crew size with power equipment showed little difference in efficiency between two-, three-, or four-man crews, but delay time was much more costly with power equipment than with hand tools for the same size trees. Skidding time per thousand board feet was determined chiefly by distance traveled, while load size and slope were secondary factors, especially with power equipment. Capacity loads should always be carried regardless of motive power, a recommendation that is often made but seldom followed.

Managing Farm Woodlands

Small woodland owners control the greatest acreage of forest land in the Southeast, but practice the poorest forest management. To serve the needs of these owners, representative small woodland tracts have been set aside by the Station at each of seven experimental forests. They are used to test and demonstrate good management practices as applied to farm woodland conditions. These tracts, under management for periods varying from 4 to 9 years, all show that the average woodland owner can obtain a good return for his labor every year while at the same time building up his growing stock. In the Southern Piedmont only 2 to 4 hours' labor per acre per year are required to realize an average annual roadside value of from $2.75 to $9.75 per acre for the products harvested. However, if a woodland owner expects to get full value from his forest, it is essential that he learn to apply a few simple management techniques such as are outlined in McClay's popular leaflet, "Managing Southern Piedmont Farm Woodlands Pays Dividends."

FOREST GENETICS

Increasing competition by lumber and veneer plants for the dwindling supply of high-quality timber plus a continued expansion of the pulpwood industry brings into sharp focus the need for full productivity of forest land. As a result, reforestation of idle land proceeds at an increased tempo, forest tree nurseries are being deluged with orders for seedlings, and many new nurseries are being established. This unprece-

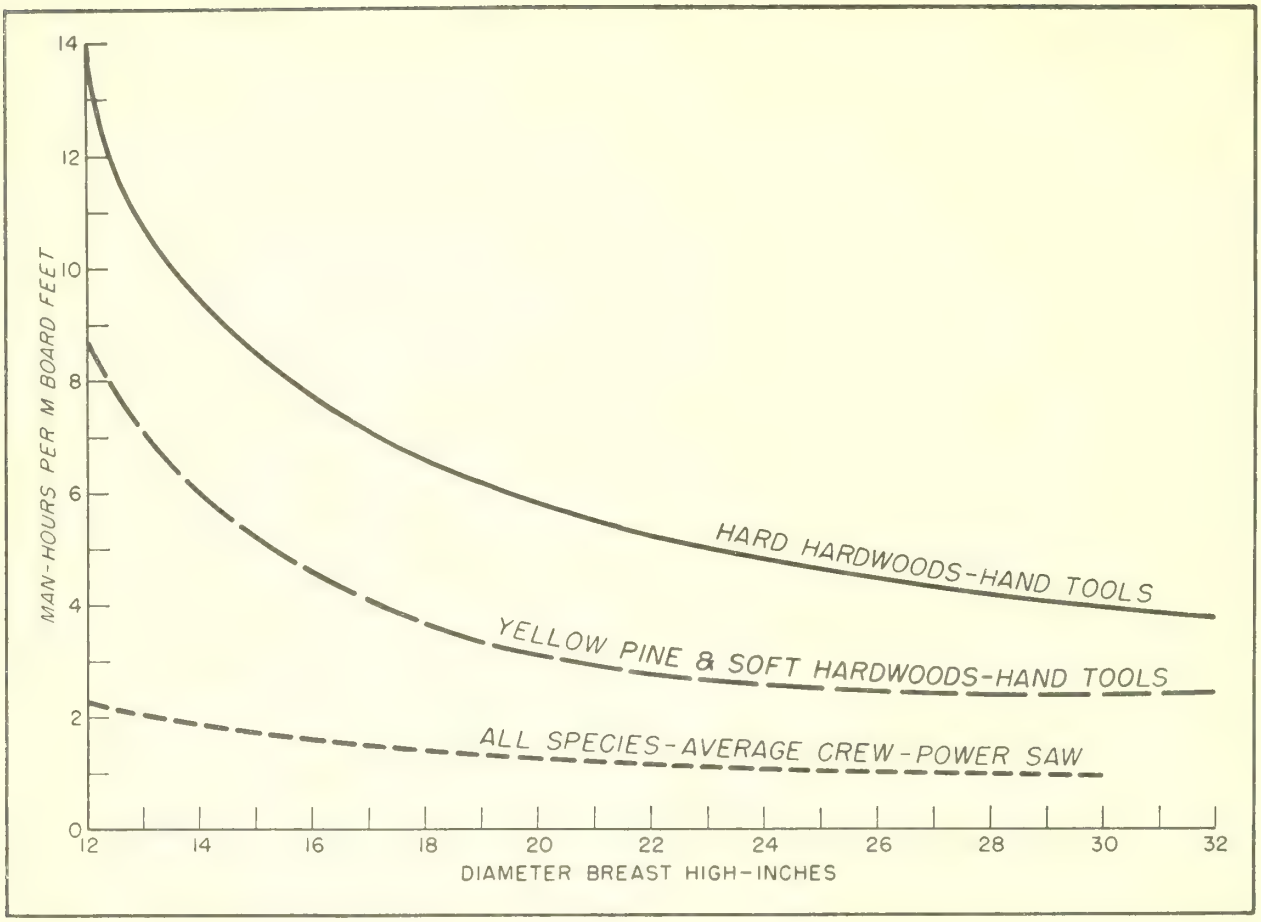

Figure 2.--Relation of felling and bucking time to tree size for different species groups in the Southern Appalachians.

dented demand can only be satisfied with correspondingly large quantities of seed which, quite naturally, are being obtained by local collectors where most abundant and cheapest. These collectors, having little interest in timber production, often pick cones without regard to the vigor, quality, or disease resistance of parent trees, but seek only those prolific specimens which are easiest to climb. This practice plus the creaming of natural stands for high quality products leads to degeneration of the crop. Thus landowners while stimulating reforestation efforts at present may be penalized in the future by the slow growth of inferior stands.

The genetic quality of the present forests can be maintained and those of the future improved by: (1) establishing new stands by planting or natural methods with seed from the best trees in the best stands; (2) making tests, with seed or grafted material of the best trees, stands, and races to isolate the best types, so that superior seed can be produced in the future; (3) starting a program of tree breeding to create new types.

This three-point program is the basis of Station activity in forest genetics. Detailed reports of "Geographic Differences in Cone-opening in Sand Pine," "Slash Pine (Pinus elliottii) its Nomenclature and Varieties," "Hereditary Variation as the Basis for Selecting Superior Forest Trees," "Suggested Projects in the Genetic Improvement of Southern Forest Trees," and "Directory of Forest Genetics Activities in the South," were published in 1952. The last three were prepared by or for the Committee on Southern Forest Tree Improvement, a South-wide group representing federal, State, industrial, and educational forestry interests.

The attempt to obtain better strains of slash, longleaf, loblolly, and shortleaf pine through individual tree selection in natural stands has been continued by K. W. Dorman in cooperation with the Ida Cason Callaway Foundation at Hamilton, Georgia. Progeny of some outstanding mother trees, even though the male parent is unknown, are as much as 50 percent taller at the end of one growing season in the nursery bed than those from other trees or from seed of commercial source. These seedling heights were compared on the basis of weight per thousand seed at time of planting. This has been true for the 1951 and the 1952 plantings.

At Lake City, Florida, evidence just obtained shows for the first time that oleoresin yield is an inherited character in longleaf pine. This study, begun in 1935, indicates the long-term nature of most forest genetics work and emphasizes the need for an early attack on fundamental problems.

Other studies at Lake City include hybridization tests with longleaf, slash, pond, and sand pine; development of improved propagation techniques; selection and outplanting of unusual specimens found among nursery-grown seedlings; establishment of two plots for demonstration of eugenic thinning operations, and conversion of existing stands into seed orchards.

Several of the Station's research centers are among the many participants in a major cooperative seed-source study of longleaf, slash, loblolly, and shortleaf pines. The study is spearheaded by the Southern Forest Experiment Station, under the sponsorship of the Committee on Southern Forest Tree Improvement.

NAVAL STORES

Bark chipping and acid treatment, a development of the Lake City Research Center, is rapidly becoming the accepted method of turpentining. In 1952 sulfuric acid was applied to nearly 20 million faces or about one-third of all those being worked. The new technique, when applied on a 14-day schedule, results in a 40- to 50-percent saving in the labor of chipping. This is a welcome saving to an industry currently plagued with labor shortages and mounting costs of production.

Techniques of Turpentining

Ten years' work with more than 70 pilot-plant operators indicates that thorough supervision of wood laborers is the secret of efficient,

economical gum production. Good supervisors insist upon (1) tight tin installations with minimum damage to the tree; (2) regular chipping schedules; (3) sharp bark hacks and good spray guns; (4) clean bark streaks of full face width; (5) uniform acid treatment from shoulder to shoulder at the point where wood and bark meet; and (6) prompt utilization of worked-out trees so that a new crop may be started.

Research in the development of better turpentining techniques is continuing with tests of gutter installations, variations in chipping interval and height of streak, and the effect of various physical factors on the yield of gum.

Gum Flow

An easily determined index of the gum-yielding ability of individual trees is essential for small-scale tests of turpentining techniques as well as for progeny testing in species improvement studies. Observations of gum-flow-rate patterns reveal that the yield from a single acid-treated bark streak applied in mid-summer is an excellent measure of the total yield from the same tree during an entire current season. This finding may greatly reduce the amount of woods labor involved in turpentine research and increase the precision of individual experiments.

Naval Stores Equipment

New or improved tools are needed for efficient application of the newly developed turpentining techniques. In earlier years engineers in the Equipment Project developed acid spray guns, spiral gutters, larger cups, spray-hacks, and spray pullers. To these have been added a rossing tool for removal of rough bark from trees about to be turpentined, and a nail-pulling device so that worked-out faces may be left free of metal. In addition the equipment engineers supervised a graduate student in the School of Engineering, University of Florida, in development and construction of a tool for sowing sand pine seeds.

COMPARTMENT MANAGEMENT

Long-term studies involving length of rotation, cutting cycle, silvicultural system, intensity of stand improvement, and the integration of turpentining, timber production, prescribed burning and grazing are being conducted on 5 experimental forests. These studies embrace 166 compartments of 30 to 100 acres in size. Formative cuts have been completed and preliminary results published for a majority of the areas. These compartments are of immediate value as a testing ground for results from small-scale, plot-type studies. On a broader scale, they provide opportunities for study of forest-land management practices and their interrelationships during successive cutting periods.

PILOT-PLANT MANAGEMENT

A 2200-acre tract on the George Walton Experimental Forest near Cordele, Georgia, is being devoted to a pilot-plant test of sustained-yield

management. The objective is to test the highest type of management that can be applied and to determine its profitability. Although only under fire protection and intensive management for 5 years, the project is beginning to produce interesting results.

Repeat measurements on a portion of the tract indicate that understocked young longleaf and slash pine stands are increasing in growth at a calculated rate of 27 percent in board-foot volume annually. Although saw-timber stands of merchantable size only occupy 56 percent of the total area, volume is increasing at the rate of 235 board feet annually.

This pilot-plant area was selected initially as representative of the middle Coastal Plain of Georgia. It is showing how the understocked stands common to the region can be built up rapidly by judicious timber cutting.

FOREST ECONOMICS

Timber Inventory of Georgia 79 Percent Complete

During 1952 the timber inventory of Georgia was completed in fifty-nine counties located chiefly in the southern Piedmont. The total area of forest land surveyed last year amounted to eight million acres. By the end of the year, the field crews had measured the timber on 6,766 sample plots, including those taken in 1950 and 1951, or 79 percent of the total scheduled for the State. Interest in the survey, on the part of forest industry and State agencies, continued at a high level as the Union Bag and Paper Corp., the Macon Kraft Co., the West Virginia Pulp and Paper Co., the Georgia Forestry Commission, and the Georgia School of Forestry all contributed to the progress of the field work.

Survey Reveals Improved Pine Timber Supply in Southeast Georgia

The southeastern Coastal Plain section of Georgia provides nearly one-half of the pine pulpwood cut in the State and a large part of the saw timber. In view of this heavy drain, up-to-date statistics showing the trend in timber supply are essential. Completion of the field inventory in southeast Georgia (Survey Unit 1) highlights the changes which have taken place between the original survey of 1934 and 1952. The total forest area has increased about three percent, but the acreage of pine types has decreased by nearly 750,000 acres. In spite of this reduction in pine acreage, improved fire protection and forest management practices have resulted in a 68-percent increase in stocking of sound pine trees 1.0 inches d.b.h. and larger. Saw-timber-size trees were 37 percent more abundant. As a result of this increase, the volume of pine saw timber was found to be 21 percent greater than in 1934. The volume of all pine timber 5.0 inches d.b.h. and larger increased 25 percent. These facts show that the forestry programs in this area are achieving results and also indicate

that the planned expansion of forest industrial capacity in this area is on a sound basis from the standpoint of raw material supply.

Techniques Improved for Predicting Growth

Estimates of timber growth prepared by the Forest Survey have for many years been based on the expected change during a specified period due to (1) increase in current growing stock volume; (2) ingrowth, or volume in trees which grow into merchantable sizes; and (3) mortality, or the volume in trees expected to die. An accurate determination of the volume of ingrowth is one of the most difficult to make, yet it is a very important part of any realistic growth estimate.

A number of methods of growth prediction have been used in the past but these are open to criticism because of the theoretical assumptions used. A revised method of computing ingrowth based on the growth of sample trees has now been developed.

The sample tree data obtained from ground plots are used to determine the proportion of trees now of volume size which were seedlings or saplings at the beginning of the 10-year growth period, or which started growing during the period. These proportions are applied to the current stand table to compute the total number of trees which reached the 6-inch diameter class during the past 10 years. Rates of diameter growth for individual sample trees are then tabulated to find out which year during the period each tree reached volume size. These tabulations are summarized and the number of trees recruiting each year are analyzed to detect trends in ingrowth which develop from better stocking of young trees or changes in stand structure. If a positive or negative trend exists, a regression curve or a simple average for late years during the period can be used to predict the number of trees which will reach pole size during the following year. Similar procedures are used to predict the number of trees which will recruit to saw-timber size. Volume tables are then applied to estimate the volume of annual ingrowth. In south Georgia, where inventory work was recently completed, this procedure showed a rate of ingrowth double that obtainable under previous methods because it took into account the progressive increase in the number of young trees in the stands.

Rate of Timber Use and Replacement High

Under a new system of tallying stumps on inventory plots to obtain drain estimates, the annual volume of pine timber drain in south Georgia (Units 1 and 2) was found to be 1,152 million board feet, or 8.6 percent of the available growing stock. This rate is surprisingly high since it means that the typical saw-timber stand is partially cut every twelfth year. A tabulation of areas on which stumps of recently cut trees were found also reveals that some timber cutting takes place on approximately 7 percent of the forest land area each year.

The rate of pine timber replacement through growth is also high for this area. In recent years the number of trees in the pole and sap-

ling sizes has been building up. This condition has created a sharp increase in the volume of ingrowth as these smaller trees reach saw-timber size. The average growth rate of pine timber under all conditions was 9.7 percent. In rapidly growing pole-timber stands the rate was as high as 13 percent.

Progress Made In Resurvey of North Carolina

With the cooperation of the North Carolina Department of Conservation and Development and its Division of Forestry, the field inventory of timber in southeast North Carolina (Survey Unit 1) was completed. Thus, as soon as office computations are finished, new timber statistics for nearly one-third of the forested area in the State will be available. This information is badly needed in this area, where the demand for timber has increased with the opening of one large new pulp mill and the development of a number of large barge and rail yards for the concentration of pulpwood. Reliable estimates of timber volume, growth, and drain will help to guide pulpwood procurement into timbered areas capable of supporting a heavier cut, thus minimizing overcutting around these concentration points.

Report on 1951 Production of Pulpwood Aids Industry

In 1951, pulpwood production in the Southeast (Station territory) amounted to 7.7 million cords, 13 percent more than in 1950. Hardwood pulpwood production, exclusive of chestnut, was 21 percent greater than in 1950. Georgia was the leading producer, accounting for 31 percent of all pulpwood cut in the Southeast. Reports on the production from each county were obtained and published. This county information continued to be useful to pulp companies as it made possible various analyses for specific wood procurement territories, usually composed of irregular groups of counties. Such analyses included the competitive relationship of pulpwood production, the intensity of production in relation to the total amount of growing stock, and the location of new areas from which to obtain pulpwood.

Sawmill Waste a Potential Source of Pulpwood

Southeastern sawmills are now turning out about 7 billion board feet of lumber annually. In the process, they also produce as waste some 7 million cords of saw-timber topwood, slabs, and edging strips suitable for chipping and conversion to paper pulp, building board, or other products. Yet the only present use for most of this material is as low-grade firewood. Recently, however, there has been great interest in waste salvage, particularly on the part of the pulp and paper industry and, with stumpage at its present high level, salvage operations may prove economically feasible. A waste marketing study being conducted by the Station in the South Carolina Piedmont highlights some of the potentialities and problems involved.

The study area is a circle of 30-mile radius, taking in portions of 11 typical Piedmont counties. It contains 147 active sawmills whose

production rates range from a few thousand to 3 million board feet per year. In 1951, they produced a total of 81.4 million board feet, 82 percent of which was pine. They also produced 50 thousand cords of mill waste and 36 thousand cords of logging waste suitable for chipping. This is equal to 40 percent of the present pulpwood production in the area.

The mill waste for an individual timber tract is usually concentrated at one mill set, occasionally at two or even three. Therefore, it would presumably not be difficult to load and transport. The logging waste, on the other hand, is widely scattered through the woods. Whether or not it is operable for a product such as pulpwood largely depends on its concentration or volume per acre. Waste volume per acre on 105 tracts examined ranged from 0.3 to 3.2 cords. However, only 14 percent of the total waste was in concentrations of less than one cord per acre; 58 percent was in concentrations of one to two cords; 28 percent in concentrations of more than two cords. Individual tracts ranged from 1 to 500 acres in size and averaged 77. There still remains to be determined the minimum operable volumes of logging waste, both per acre and per tract, and the most efficient methods of preparing, assembling, and transporting all classes of waste to market.

WATERSHED MANAGEMENT

Protecting Watershed Values by Good Forest Road Construction

Careless methods of forest road construction jeopardize water quality by adding to the turbidity and sediment in the streams. This occurs not only during use of logging roads but on one logged watershed at Coweeta the adverse conditions continued for 4 years following logging.

Good surface drainage of roads is a key factor in maintaining water quality as well as in minimizing road maintenance and equipment repairs. Problems in road drainage design and techniques for handling surface storm water were studied on temporary work roads and skid trails in mountain logging operations at Coweeta. It was found that self-cleaning properties for open top surface drains can be maintained when the length of the storm drain extending diagonally across the road is approximately twice the berm-to-bank road width. This means that the volume of storm water should not be so great that forest litter is unable to filter out the sediment before it reaches the stream channel. Information was obtained in 1952 on discharge of sediment from open top storm drains on forest roads having various grades and drainage spacings (fig. 3). These studies showed that when 20 cu.ft. or less of sediment per year is discharged from one of these drains, the forest litter filters it out, the storm water quickly soaks into the soil, and no pronounced rilling or wheel-rut wash occurs. Where 140 cu.ft. or more of sediment is discharged annually at one point, active gullying

occurs on the road surface and in wheel ruts, creating hazardous road conditions, increasing maintenance costs and decreasing traffic loads. The effect of these and intermediate practices upon watershed values is indicated in figure 3.

Effect of Land Use and Forest Management Practices on Trout Streams

Field work on a cooperative project with the North Carolina Wildlife Resources Commission and the U. S. Fish and Wildlife Service was begun in 1952. Sampling of fauna and flora along stream bottoms is under way. This information together with hydrologic data collected at Coweeta will be used to evaluate the effect of various land use and forest management practices on trout stream environment.

Stream temperature studies at Coweeta are giving a new concept for managing streambank vegetation. Following cutting of the laurel and rhododendron understory on a 70-acre watershed at Coweeta, water temperatures were maintained within limits of tolerance for trout. This cutting actually increased the period of optimum temperature necessary for growth and development of trout and the aquatic organisms upon which they feed. Clearing of riparian vegetation for limited stretches along a stream showed that it is possible to keep temperatures within optimum limits and in the open area produce more aquatic organisms plus better opportunities for fly fishing.

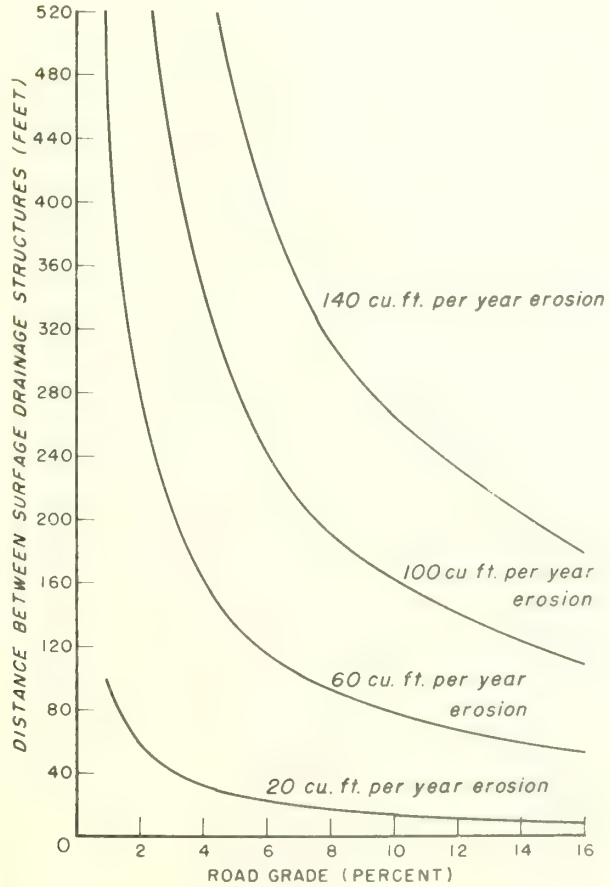

Figure 3.--Soil losses depend on road grade and distance between surface drainage structures.

Clearing of riparian vegetation along extended stretches of streams too small to sustain a fish population greatly increases stream temperature. With high temperatures, aquatic organisms far out of proportion to the stream's size are produced and flushed into the main channel, thus providing more trout food there. Consequently, a slight rise in water temperature of forested streams may be advantageous.

Basic Hydrologic Research

Records from 31 stream gages, 8 turbidity stations, 6 water temperature stations, 26 observation wells, 9 weather stations, 18 recording rain gages and 88 standard rain gage stations were taken currently at Coweeta during 1952. In cooperation with several universities, basic hydrologic data accumulated in the past from Coweeta were analyzed in the preparation of several graduate theses by students working part time at Coweeta. Based on these data in 1952, one Ph.D. was awarded, and two Ph.D. and three Master's theses were in progress.

Practical Value of Watershed Research

Furnishing information on water resource management and forest influences occupied a major portion of the Coweeta staff's time during 1952. Two training sessions each requiring 2 or more days, 11 illustrated discussions, and 65 tours were conducted for 754 visitors. In addition, over 60 inquiries on the technical phases of the research program were handled on a consulting basis or by correspondence. To help facilitate the dissemination of research findings at Coweeta, a movie, "Waters of Coweeta," was prepared. This film will inform people who cannot come to the area about Forest Service watershed management research in the Southern Appalachians and provide facts regarding land use practices.

Plans for 1953

Publications will be emphasized in 1953. Plans are to complete a report summarizing 17 years' research at Coweeta. Several papers will be written on basic research projects covering hydrology, forest management practices, and soils as they relate to stream flow. A long-range program conference is scheduled for April 1953. This conference will review research needs for continuing existing watershed treatments and suggest priorities for proposed watershed studies on land use, evaporation-transpiration studies, and integrating the silvicultural aspects of forest management and water resource management. The basic research projects on soils, climate and hydrology as they relate to stream flow will be continued.

FOREST SOIL-WATER RELATIONS IN THE PIEDMONT[1/]

The objectives of watershed management research at the Station's Piedmont Research Center are: (1) to learn what conditions are on forested watershed lands; (2) to work out methods for improving conditions where they are now unfavorable; (3) to develop practices which maintain present favorable conditions; and (4) to plan research so that results will promote a better fundamental understanding of watershed management.

Areas which have lost the original topsoil and are now barren or gullied constitute the most serious regional problem so far as erosion and floods are concerned. It is estimated that in the aggregate such areas constitute about 5 percent of the forested area. The majority of eroded material that muddies streams comes from these areas plus poorly farmed lands and old roads. Any rainfall in excess of an intensity of 0.10 inch per hour runs off from these areas. An ordinary thunderstorm of less than 1 inch of rain causes a muddy torrent to pour off these scalds and galls.

Where the original topsoil has not all been lost and a sandy surface remains, conditions are less serious and natural vegetation controls erosion. A good cover of broomsedge protects the soil surface but does little to loosen up the underlying heavy clay. Effective moisture storage during heavy rains occurs only in the topsoil layer. Where 4 to 6 inches of topsoil remain, an area in broomsedge has the capacity to store from 1.5 to 2.0 inches of rainfall before surface runoff begins. Although this is much better than a bare eroded area, surface runoff would still occur from about 25 storms per year.

The establishment of trees with their deeper-ranging root systems causes an increase in the permeability of the underlying clay and increases the capacity of the soil to store water. A 20- to 40-year-old pine forest on an old field site generally can store from 2.5 to 4.0 inches of rainfall in a 24-hour period. This capacity would be exceeded less than 7 times in an average year. With the passage of time the ability of the young forest to store rainfall increases, and eventually may reach that now found on the remnants of old growth forest. Measurements in the patches of old growth remaining indicate a storage capacity of more than 9 inches for a 24-hour period, and only rarely do storms exceed that capacity.

As a check on these determinations and to furnish further information, stream flow is measured on 4 small watersheds, and soil moisture observations have been taken under typical plant cover types to a depth of 6 feet in the soil. The soil moisture records show that tree roots draw moisture to depths below 6 feet and, in fact, it appears to be normal for trees to use all available water in the upper 6 feet of soil before the end of the growing season. Broomsedge with associated herbaceous vegetation has a more limited root system and normally dries the soil to wilt-

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1/ Joint project of Divisions of Watershed Management and Timber Management.

ing percentage only in the surface 3 feet of soil. On bare soil, evaporation dries the surface rapidly but the rate diminishes with depth, and even in the driest weather there is available moisture below 24 inches.

During the winter of 1950-51, rainfall was not sufficient to add moisture to depths below 3 feet in forested areas and because of this trees had little soil moisture available. In fact, after May 15, 1951, trees were almost completely dependent on current rainfall to meet their moisture needs. This helps explain the insect build-up and poor growth experienced during 1951. The early summer of 1952 was extremely hot and dry but forest growth suffered little, if any, because rainfall of the preceding winter was sufficient to raise the soil to field capacity during March. As a result, the surface 6 feet of soil had 7 inches more available moisture on April 1, 1952, than was present in 1951.

The job of restoring water storage capacity and fertility to the eroded soils of the Piedmont begins with improvement of the surface layers. This improvement will be brought about primarily by the vegetation on the site through the organic matter it adds to the forest floor. In order to find out how much organic material is added to the forest floor under various stand conditions, litter fall studies have been in operation for two years. Average values for the two years for stands growing in Union County, S. C., are given in the following table:

Table 2.--Organic matter added annually to forest floor beneath various Piedmont stands (oven-dry basis)

Stand composition	Leaf fall	Litter fall 1/
	Pounds per acre	Pounds per acre
75% loblolly, 25% shortleaf pine, age 26	3,685	4,733
Shortleaf pine, age 35	2,836	3,725
Loblolly pine plantation, age 11	3,461	3,885
Shortleaf pine-hardwoods, age 1-40	3,179	4,115
Hardwoods, age 1-50	3,600	4,372
Hardwoods, age 1-150	4,022	4,862

1/ Includes leaves, twigs, bark, and fruit.

Table 2 shows in general that leaf and litter fall are independent of species and age. From the above values a good working figure for leaf fall for Piedmont stands is 3500 pounds per acre, and for litter fall 4300 pounds. Although the quantity of organic material added varies little between the stands, the amount of nitrogen and calcium is much different. The leaf fall from pine stands contained 13 pounds of nitrogen and 18

pounds of calcium, whereas that from the hardwood stands contained 27 pounds of nitrogen and 88 pounds of calcium, per acre.

The quantity and quality of the material added to the forest floor determines to a large extent the amount of organic matter that is incorporated into the mineral soil. This incorporated organic matter is important because of the desirable physical and chemical characteristics it imparts to the soil. Table 3 gives the organic matter content of soils beneath Piedmont, Coastal Plain and Mountain forest stands.

Table 3.--Percent organic matter based on oven-dry weight of soil

Sample depth (Inches)	Union County, S. C.			Santee, S. C.	Coweeta, N. C.
	Aver. of three pine stands	Hardwoods 50 yrs. old	Hardwoods 150 yrs. old	Loblolly 50 yrs. old	Hardwoods old growth
0-1	1.37	6.07	10.24	11.21	12.83
1-2	1.01	3.68	5.85	5.63	7.87
2-4	.93	2.60	3.59	3.13	5.21
4-6	.84	2.07	2.21	1.70	3.82
6-8	.76	1.82	1.52	1.30	3.70
8-10	.69	1.84	1.25	1.12	2.25
10-12	.59	1.82	.91	1.10	1.71

Table 3 indicates that old field pine soils have a very meagre supply of organic matter. However, the potentialities of the soil are evident when one compares the 150-year-old Piedmont hardwood stand with the Santee and Coweeta stands. The Santee samples were collected near Charleston, South Carolina, and the Coweeta samples from the mountains of North Carolina on soil which has never been cleared.

Table 4 shows the nitrogen that is found in these same profiles. This table shows the general low nitrogen level of old field pine sites of the Piedmont. The importance of nitrogen to tree growth in the Piedmont region has been brought out by studies of the littleleaf disease by the Division of Forest Pathology.

Future studies will be concerned with evaluating the factors which determine the organic matter content of the soil and the physical properties which increase water storage capacity.

Table 4.--Percent nitrogen based on oven-dry weight of soil

Sample depth (Inches)	Union County, S. C.			Santee, S. C.	Coweeta, N. C.
	Aver. of three pine stands	Hardwoods 50 yrs. old	Hardwoods 150 yrs. old	Loblolly 50 yrs. old	Hardwoods old growth
0-1	.043	.175	.287	.320	.365
1-2	.033	.108	.169	.163	.226
2-4	.031	.078	.106	.093	.151
4-6	.029	.063	.067	.053	.112
6-8	.026	.056	.048	.041	.109
8-10	.024	.057	.040	.036	.068
10-12	.022	.056	.031	.035	.053

FIRE RESEARCH

Cumulative Danger Index

The Southern Appalachian region experienced one of the worst fall fire seasons in its history during the period mid-October to mid-November 1952. A prolonged drought plus occasional days of high wind taxed control agencies to the utmost.

One method of gaging the severity of the period is illustrated in figure 4. On it is shown a comparison of build-up for three different areas. The West Virginia and Kentucky curves show build-up during the critical burning period in the autumn of 1952. Similar conditions prevailed in many of the eastern states. The Maine curve represents build-up during the 1947 period of disastrous fires.

Steps involved in the derivation of a cumulative danger index cannot be briefly explained. Essentially, however, they consist of adding or subtracting daily departures from the "normal," established for each geographic unit by median data collected over a period of 8 years. Daily records are obtained through the use of a 100-point danger meter which integrates a number of variables measured at fire danger stations. Therefore, the cumulative danger index indicates the build-up of forest flammability above normal. An adjustment is made for rain: one inch or more of rain reduces the cumulative danger index to zero, and lesser rains in proportion.

Thus, during periods of normal fire weather the cumulative danger index remains at or near zero. During period of drought, when above-

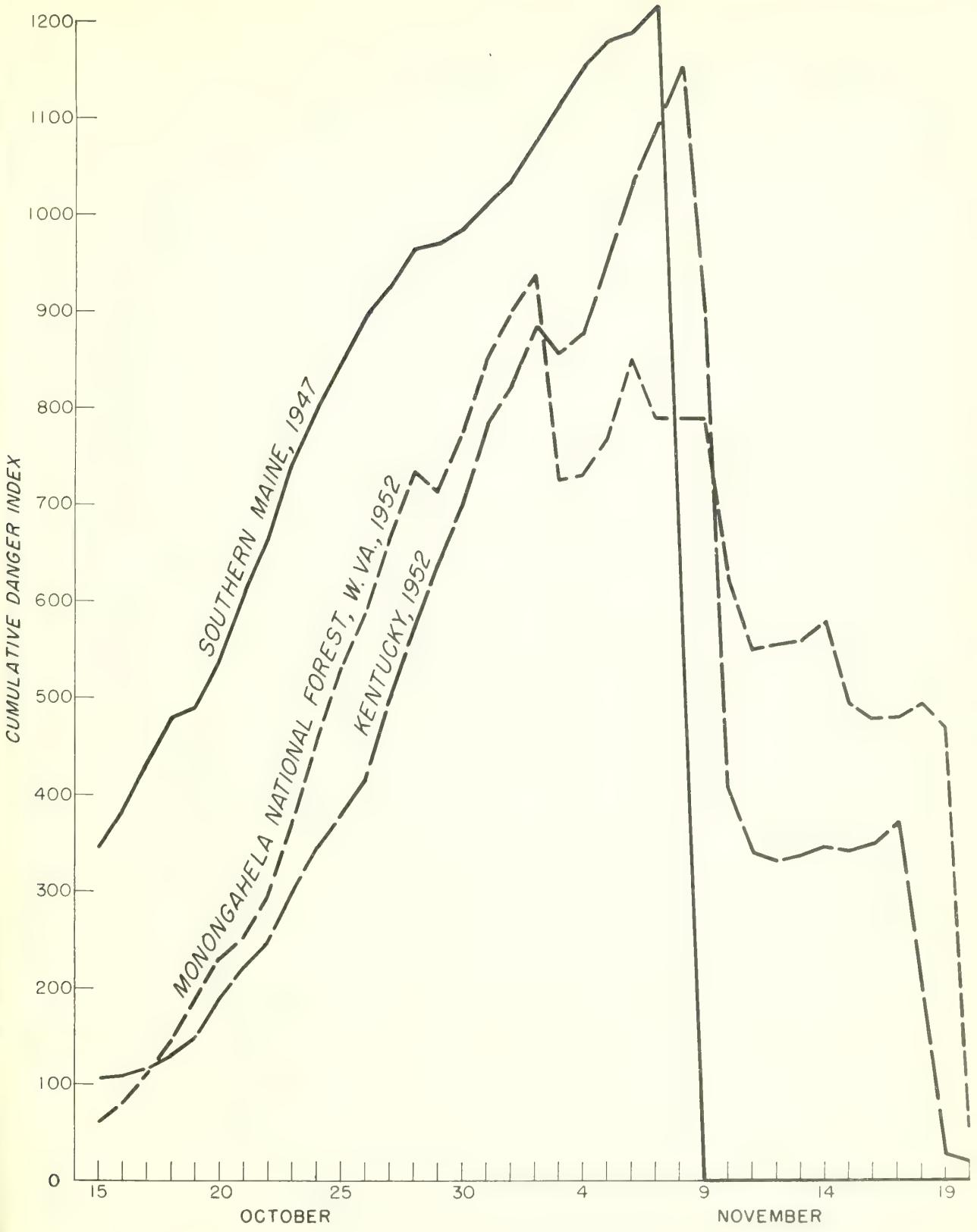


Figure 4.--Cumulative danger index curves.

normal burning index is measured, the cumulative danger index increases, sometimes to several hundred units, depending on the daily burning index and the duration of the drought. Any appreciable relief thereafter can only come from rain.

As shown by the graph, build-up of danger in the three areas was similar. This does not mean that the job load was the same for each, because many variables such as fuel type, flexibility and strength of organization, and soundness of attack are involved. The curves show, however, steadily worsening conditions as the season advanced.

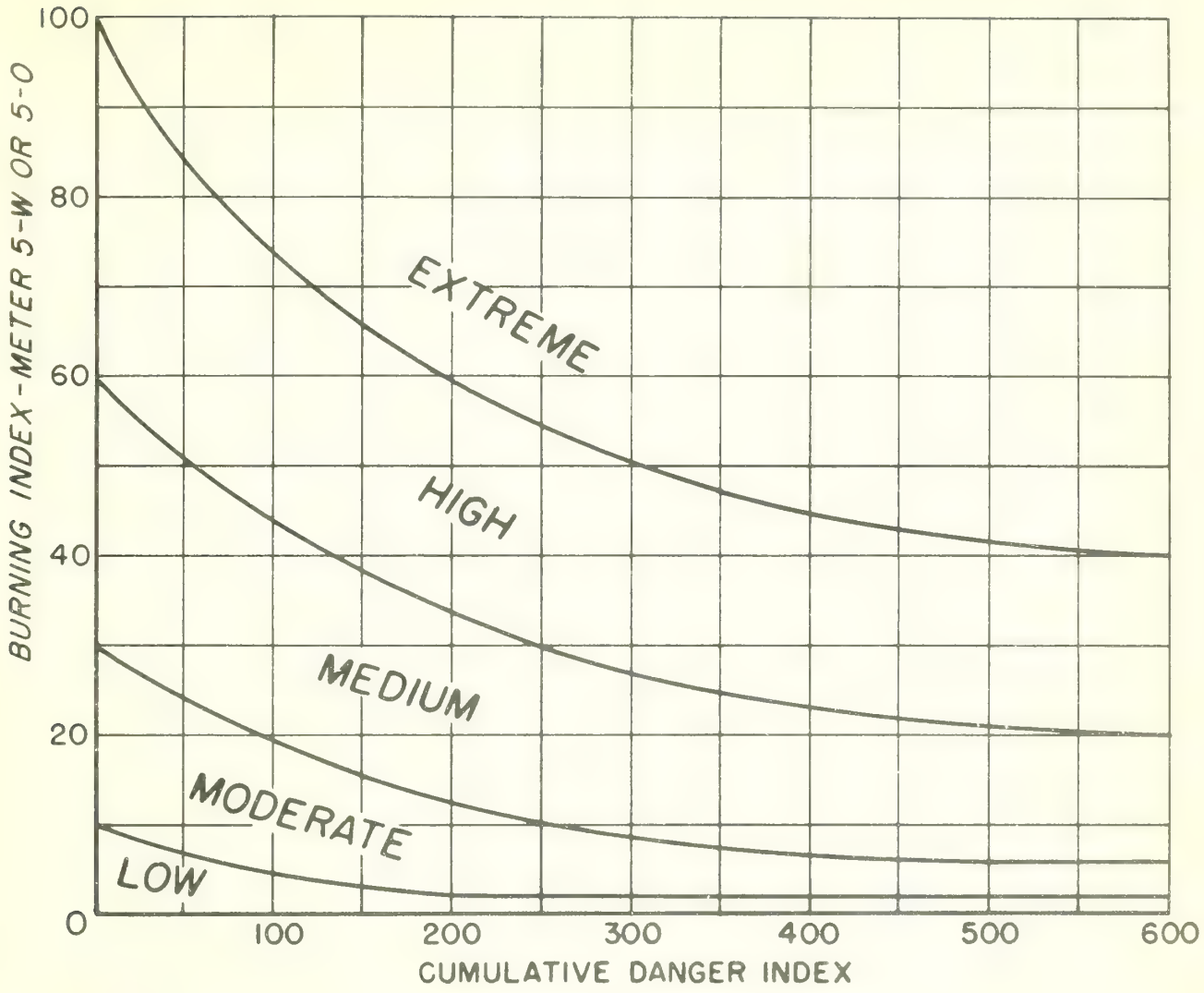
The cumulative danger index serves a useful purpose by alerting fire control organizations when above normal conditions exist. It is now in general use in the Northeast and in parts of the Southeast. On the basis of past records, woods have been closed in the "compact" States of New England and New York when the cumulative danger index averaged 200, and some areas have been partially closed at 100. Last fall, for example, Rhode Island woods were closed on the day the cumulative danger index reached 193.

Its use also forewarns of dangerous conditions during the "off fire season" months when fire control organizations are ordinarily not alerted. For example, in eastern Pennsylvania last summer on the Hazleton Unit the cumulative danger index exceeded 200 from June 12 through July 8. During this period a partial tower system was manned and extended mop-up and patrol was needed because of deep-burning fires. Increased resistance to control was also reported from this unit in October as the cumulative danger index mounted toward 300.

Similar reports from West Virginia, Kentucky, and other sections of the Northeast have suggested the need for a method of integrating the daily burning index and cumulative danger index so that preparedness would be stepped up during periods of drought. A tentative schedule for doing this is illustrated by the curves and recommended action shown in figure 5. The curves are theoretical and may be modified as experience dictates, and the action taken would, of course, vary to fit local conditions. Development of the cumulative danger index and its several uses are largely the work of collaborator J. J. Keetch, of Region 7.

Fire Danger Stations

Of the 374 fire danger meters requested by fire control agencies in eastern and southern states and furnished by the Station in 1952, 336, or 90 percent, were those with the 100-point scale. This is strong indication of preference for the 100-point scale over the earlier types that had only a few class gradations. Nine out of ten of the 100-point type meters were either type 5 or type 5-C, which give directly comparable indexes in the proportion of 1 to 2; the type 5 is standard for all the northeastern states and the type 5-C, for practical purposes, may now be considered standard for the southern group. The transition to the new type meters, which has been progressive since their introduction in the Northeast in 1947, is about complete. Hence, fire danger ratings based upon suitably located stations are now comparable from Maine to Texas.



Recommended Action

LOW--No fire control organization - issue burning permits.
MODERATE--Primary detection - skeleton organization - issue burning permits with caution below C.D.I. of 200.
MEDIUM--Full detection - complete full-time organization alerted.
HIGH--Fire control organization at peak strength. Patrols and standby crews on duty if needed because of poor visibility or other conditions.
EXTREME--Emergency condition - use emergency plans augmenting local facilities.
Note: During periods of high risk, such as hunting season, low visibility, etc., preparedness may be advanced one step.

Figure 5.--Integrating cumulative danger index with daily burning index (usually predicted 24 hours ahead). Some readers may wonder how a low state of preparedness can be justified when the cumulative danger index is up to five or six hundred. This would only occur on days of fog or light rain during a long drought; the situation is still potentially dangerous.

This greatly facilitates training programs, fire control planning, fire damage appraisals, and other fire activities which can best be done by sections or regions.

A considerable portion of the Division's effort during the year went into improving danger measurements and techniques, supplying and locating stations, training observers and inspecting their work, and analyzing records.

Atmospheric Stability and "Blow-up" Fires

In the light of present knowledge, four essentials for severe and erratic fire behavior are: plentiful fuels made inflammable by prolonged drought; dense conifer stands; a deep unstable or neutrally stable atmosphere, the lowest few hundred feet of which may be stable or unstable; and a critical wind speed and low wind shear (wind shear is the rate of change of wind speed with height). The first two factors were fairly well understood 2 years ago. During 1952 much more has been learned about the third factor. The possible importance of the fourth factor has become evident only within the last year. Investigations are continuing to determine the effect of low wind shear and critical wind speed on fire behavior characteristics, such as whirlwinds and updrafts.

Methods were worked out in 1952 for computing the temperature profile of an unstable atmosphere from radiosonde records.

There appear to be at least two meteorological conditions associated with the instability of the atmosphere on those days when unusual or severe fires have occurred. The atmosphere may be unstable in a region over which a cold front is passing, in which case the winds will be from the north or northwest. The atmosphere may also be unstable in the northwest quadrant of a stagnated high pressure area; winds in that quadrant would be from the south or southwest.

The most important development during 1952 concerned the heat engine analogy. This thermodynamic analysis has not yet been completed, but has either answered or indicated the answer to some of the more difficult problems of the study, such as the source and magnitude of the unusual turbulent energy of severe fires and the reasons why some of the worst fires occur at night. Most of the turbulent energy comes from the conversion of a fire's heat or thermal energy into the kinetic or turbulent form. The energy conversion process occurs in the convection column above the fire, but it can take place on a large scale only when certain stability conditions exist in the atmosphere.

The heat engine concept gives us a better picture of the "blow-up" process as well as a better understanding of the more general problem of the relation of the behavior of any fire, large or small, to the properties of the surrounding atmosphere.

FOREST UTILIZATION SERVICE

The reduction of wood waste keynoted the activities of the Forest Utilization Service in 1952. Since it was a busy year for southeastern wood-using industries, demands on the forests were heavy, resulting in more interest than ever in utilizing waste material.

In the interest of reducing waste and improving the amount of usable lumber, four short courses in sawmilling were conducted during the year and numerous sawmills were advised on proper methods of logging, grading, sawing, and seasoning lumber and wood products.

By sorting logs for their best use, waste, costs, and manpower can be reduced. An extensive study was made of factors affecting the quality of southern hardwood veneer logs and blocks. This included photographs of the defects on the surface of the veneer logs and subsequent photographs of the defects as the veneer was peeled down 1 inch, 2 inches, 3 inches, and on to the center of the logs. This research is the first step in the development of veneer log grades which will be vastly helpful in producing better products at lower cost. Two schools were conducted to teach foresters and industry representatives the methods of grading hardwood and pine logs and trees. The hardwood log grades were simplified and reduced to a grading stick so that an inexperienced person can readily compute the grade of the log from the information given on the stick.

As a direct result of the pine log grading school, one company had its research forester carefully grade several hundred pine logs and follow them through the mill, tallying the grade and footage obtained from each log. The Station is cooperating in an analysis of the data obtained, since valuable grade-yield information can be derived while assisting the company in the evaluation of the grading system.

A straw in the wind was a forestry workshop held in western North Carolina in 1952 at which approximately 30 teachers from the grammar and high schools of North Carolina spent 6 weeks accumulating information that they could pass on to the next generation of citizens. Forest utilization men conducting courses at the workshop were impressed by the teachers' interest in wood utilization and their concern for greater use of the slabs, edgings, sawdust and tree laps that accumulate each year in the Southeast.

In more than a hundred visits to wood-using industries during 1952, every effort was made to call attention to wood waste and to point out methods where savings could be made, not only in wood but in manpower and money. Faulty seasoning is a very common cause of unnecessary loss, and in nearly every plant visited some advice could be given on improved methods in the air-drying yard or in the dry kiln. Much time was spent with dry kiln operators in meetings and at plants to give them the latest dry kiln schedules and the best methods for drying wood safely without degrade. Quality control systems were recommended so that these difficulties could be discovered and corrected at the plant rather than in the home of the purchaser of the wood product, where the only result would be to give wood a bad name.

For a number of years experiments have been made to develop an automatic furnace using low grade and waste wood to cure tobacco. The model developed in 1950 was built on two additional farms this year. One operator liked it so well that he is making plans to market the furnace next year. A report has been prepared on the progress of this work and will be published shortly. Although the wood-burning furnace proved satisfactory, the furnace fired by sawdust continues to give some difficulty at high temperatures and work must be continued for another year before it can be recommended.

Another source of waste is found in the trees bypassed in the forests by loggers because of market conditions, ignorance, or prejudice. The hickories, some of the red oaks, some of the white oaks, and others which are inherently good woods and a source of added raw materials for industry are discriminated against primarily because of lack of knowledge as to how to use them. In addition to the Forest Products Laboratory, the State forestry schools and industry have been enlisted in the research program to solve this problem. The Forest Utilization Service has emphasized assistance to an industry that is attempting to utilize hickory or one of the other species that most operators either leave in the woods or poison. The ground work has been laid for a task force approach on the utilization of hickory and during the next few years approximately 30 reports will be prepared by the Station and cooperators to summarize all information available on this species. In addition, research will be started to fill the gaps of knowledge.

Utah and alligator juniper logs from the Southwest were shipped into the territory to a firm that manufactures cedar chests from eastern red cedar. These western species were cut into veneer to see if they might be used as a substitute for the eastern red cedar. Although the color and odor were not satisfactory for use in cedar chests and similar items, it was found that the species veneered very well and might find uses in furniture or containers. The results of this study may lead to new industries in the Southwest.

The main tool of foresters in the past for controlling growth and quality of wood has been environment. Foresters are finding a new tool in genetics. The old argument of the part played by heredity as against that played by environment applies to trees as well as people, but most authorities agree that it will be necessary to consider both if best results are to be obtained. The pulp industry is vitally interested in this question of growth and quality and the part that genetics might play in the picture. During 1952 field reconnaissance indicated that great possibilities lie in this field. Plans are being made to determine fiber qualities that are most desirable for the pulp industry and to follow through in learning how to obtain these fiber qualities by manipulating environment and heredity.

The entire field of wood preservation in the Southeast has taken on new life. Small hot-and-cold bath treating plants are springing up in many parts of the South to provide treated fence posts in an expanding grazing program. Even the large pressure-treating plants are going after

this market and are now treating fence posts in quantity and marketing them at a reasonable price. Cheaper post treatments with shorter life expectancy than pressure-treated creosote posts, are being provided by the salt treating agencies. A brand new process developed by the Taylor-Colquitt Company in South Carolina provides a post treated with copper naphthenate or pentachlorophenol that removes the preservative carrier by vapor drying, leaving a treated material so clean it can be handled, painted, or finished naturally with the only evidence of its treatment being its resistance to decay and termites. Realizing the importance of wood preservation in the Southeast, the Forest Utilization Service designed and assisted in presenting the first wood preservation short course to be given in this region. Foresters from the State Forest Service and the Extension Service took the course; now they can serve as retailers to pass the information on to hundreds of persons interested in the subject. The reception to this short course was so encouraging that it will probably be repeated in several southeastern states next year.

During 1952 a start was made in a detailed analysis of the problems of the Southeastern States in wood utilization. Because of the immensity of this job one research center area in the territory will be studied at a time and, working in cooperation with the research center leader, a report will be prepared on the problems in wood utilization in that section. This report will serve as a guide to the research center leader as well as to the Forest Utilization Service. When all research center wood utilization problem analyses have been prepared, which may take 3 to 5 years, it will be possible to prepare a general wood utilization problem analysis for the entire Southeastern States.

GRAZING FOREST LANDS

Efficient utilization of the forage resource for additional income and fire protection in Coastal Plain pinelands is the objective of the Station's grazing research. All grazing studies are conducted cooperatively with other federal and State agencies.

Cane Range

Our previous research in cooperation with the North Carolina Agricultural Experiment Station has shown that grazing in the cane type can be profitable to the cattleman as well as beneficial to the forest. Recent studies have been concerned with problems of forage and cattle management.

Best grazing rates.--Utilization of 55-60 percent of the total cane herbage is the maximum degree of use commensurate with sustained yields of forage and beef under continuous summer grazing. This is one conclusion from cooperative studies being published as a North Carolina Agricultural Experiment Station Bulletin. On highly-productive treeless range, this degree of use was obtained at a stocking rate of 2.8 acres per cow and calf

for a 6-1/2 to 7-month grazing season. With daily gains of 0.6 pound per cow and 1.1 pounds per calf, total annual production averaged 111 pounds of gain per acre at this rate of stocking. Although heavier grazing temporarily yielded higher weight gains per acre (up to 148 pounds), gains per animal were lower and forage production declined. Moderate grazing also appeared desirable from the viewpoint of fire hazard. Although reduction in fire hazard was roughly proportional to the degree of grazing over a relatively short period, indications were that continued overgrazing in summer would soon kill the cane and allow it to be replaced by weeds that are more inflammable.

Cattle performance.--Winter management, range quality, and breed of cattle affect productivity of range herds. Wintered under adequate farm conditions, but depending entirely upon cane range for 8 to 9 months, grade Hereford cows in the study referred to above weaned 350- to 400-pound calves and consistently produced 85 to 90 percent calf crops over a 6-year period. When maintained yearlong on less productive range, calves of similar Hereford cows have averaged only 271 pounds at weaning time the past 2 years. However, calves of Brahman-Hereford and Africander-Hereford crossbred cows have averaged 387 and 336 pounds, respectively, under the same conditions. Apparently inadequate nutritional levels on winter range have limited calf crops to an average of 50-percent for the 2 years. Winter management of range herds is receiving additional attention in the present program.

Wiregrass Range

The value and limitations of native forage in longleaf-slash pine flatwood forests have been fairly well established in our past research with the Georgia Coastal Plain Experiment Station, and are summarized in pending State and federal publications.

Although burning improves grazing values, forage quality is not adequate to satisfy the requirements for lactation and for reproduction at the same time. Consequently, 50-percent calf crops and 275-pound calves are about all that can be expected from herds depending primarily on this kind of native range. A minimum level of fall and winter supplementation to prevent starvation death losses is approximately 1 pound of protein meal per head per day after October 15, and dry lot maintenance on hay or chopped sugarcane plus protein meal from February 1 until burned range is ready to graze in mid-March. Recent studies have explored possibilities for improving cattle production by supplementing native range in summer.

Supplementing forest range in summer.--Effects of supplementing summer range with protein meal have been studied 5 years, and the use of improved pasture as range supplement has been tested 2 years.

Supplemental protein feed increased calf weaning weights 65 pounds (360 vs. 295), and the percentage calf crop 9 percent (64 vs. 55). In addition, summer gains of nursing cows were increased 77 pounds, and dry cows 53 pounds. Approximately 250 pounds of supplement were fed per cow (2 pounds per day during the breeding season and 1 pound thereafter) plus 90 pounds per

calf. This supplemental feeding was practical only for nursing cows because dry cows usually bred successfully without summer supplement, and they lost most of the extra summer gain during the fall and winter.

Improved pasture is apparently better than protein feed for supplementing native range, according to preliminary results of tests exploring methods of integrating pasture and range for most efficient use of the cheap native forage. Compared with herds on unsupplemental range, transferring range cows to improved pasture (1-1/2 acre per cow) after July 1 increased average calf weights 156 pounds at weaning time. A limited amount of pasture (1/2 acre per cow) plus range during the same period was also effective - 129 pounds' increase. In comparison, calf weights these years were increased only 56 pounds by supplementing the range with protein meal (340 pounds per cow and calf over a 6-month period). In range herds receiving no summer supplement, weaning weights averaged 300 pounds for these two years. Evaluating the calves at 25 cents per pound, and deducting the cost of feed and pasture (establishment and maintenance only), shows increased returns per calf from the supplements as follows: limited pasture $25; full pasture $18; protein meal $6. A limited amount of supplemental improved pasture has been more effective when reserved until midsummer than when it has been continuously available, spring to fall. Continuous close grazing apparently reduced forage yields and, consequently, cattle gains. The improved pasture in these tests was a mixture of Louisiana white clover and Dallisgrass.

Improving range forage.--Past studies have shown that improved forage species can be introduced successfully into forest range. Legumes require no seedbed preparation other than burning the native sod and grazing the regrowth, but disking or chopping is desirable for introduced grasses. Although most improved species require fertilization, the requirements of some, such as lespedeza and carpetgrass, are lower than others such as big trefoil and Dallisgrass.

Relative returns from "high level" improvement with big trefoil and Dallisgrass, versus "low level" improvement with lespedeza and carpetgrass have been tested 2 years with yearling cattle. Weight gains per acre have averaged 151 pounds on big trefoil-Dallisgrass ranges, and 75 pounds on lespedeza-carpetgrass ranges. These gains are directly proportional to the rates of fertilization, 400 and 200 pounds per acre annually. Comparable gains on unimproved range were approximately 20 pounds per acre.

FOREST PATHOLOGY[2/]

Littleleaf Disease of Pine

Twelve years of research on littleleaf has been summarized in a technical bulletin manuscript to be published in 1953. The theory is developed, supported by much experimental evidence, that littleleaf results primarily from a nitrogen deficiency of the tree due to the killing of fine roots by the fungus Phytophthora cinnamomi under conditions of poor subsoil drainage. A field method has been developed for predicting the littleleaf potential of a site, based on simple soil criteria. Cutting practices to minimize littleleaf losses have also been formulated.

Programs on selection and breeding for littleleaf resistance in shortleaf pine and on the testing of 12 geographic lines in 3 states, for resistance, were started in 1952. The developments indicated above are aimed at making use of our considerable fund of knowledge on this disease in either predicting where losses will occur or in preventing and reducing losses.

Oak Wilt

Additional surveys bring the total counties where oak wilt has been found in the Southeast to the following: West Virginia, 22; Virginia, 1; Kentucky, 3; Tennessee, 6; and North Carolina, 3. This is an increase of 8 counties over 1951. The disease appears to be spreading slowly in the Southeast.

The causal fungus fruits abundantly under the bark of some diseased trees, and insects coming in contact with the spores are potential agents of spread. Twenty-three oak wilt trees were felled, and certain logs of each tree were barked, some left unbarked, some sprayed with insecticide-fungicide mixtures, and some unsprayed. Spraying logs with the bark on very greatly reduced insect activity under the bark and on the fungus mats themselves, for the first several months. Barking completely prevented the formation of fungus mats and bark and cambium insect activity.

Miscellaneous Pathology Developments

Mimosa wilt.--Mimosa seedlings dipped for 24 hours in solutions and then inoculated showed the following survival percentages from wilt at the end of the summer: Dithane (D-14) 92%, Vancide (51) 62%, Systox 22%, C-162 20%, Fermate 12%, C-1207 10%, Orthocide-406 10%, oxyquinoline benzoate 10%, water 5%. Dithane and Vancide look particularly promising for further work.

2/ Report of the Division of Forest Pathology, Bureau of Plant Industry, Soils, and Agricultural Engineering, in cooperation with the Southeastern Forest Experiment Station.

Needle cast.--The ability of Hypoderma lethale to cause spring needle blight has been demonstrated by inoculation.

Fomes annosus.--This fungus, which causes the most serious conifer plantation disease in Europe, and has caused root and butt rot elsewhere in the U. S., has been found causing extensive root rot and bark killing at the root collar in a 15-year-old slash pine plantation in South Carolina.

New Virginia pine rust.--This stem rust, described for the first time last year, has been found in additional areas in Virginia and Tennessee. At this time it is not regarded as a threat to this species although it kills trees, and its alternate host, if it has one, is not known.

White pine blister rust (B.E.P.Q. cooperating).--A 1-acre study plot in a rusted stand in Ashe County, North Carolina, at elevation of about 3500 feet, shows what the rust can do this far south.

Table 5.--Blister rust mortality on a study plot in North Carolina

Tree size in 1946	Total trees	Dead due to blister rust			
		1946	1948	1950	1952
	No.	Percent	Percent	Percent	Percent
Over 10 feet high	117	1	2	4	8
1-10 feet high	34	1	6	15	32
Under 1 foot high	100	0	2	2	8

Naval stores pathology.--Heavy pitch-soaking of the wood of certain slash and longleaf pines resulted, in a single year, from certain combinations of wounding and fusarium inoculation, and further trials were installed. All the work on prolonging gum flow and on pitch-soaking wood by fungus inoculation for the past 3 years has been brought together in a single report.

Blight resistant chestnuts.--A large number of demonstration plantings of high-quality Chinese chestnuts planted on good sites have been established throughout the Southeast, as far south as Florida.

Service to the Navy.--Much of the time of one man during 1952 has gone toward the inspection and treatment of wooden boats for decay and in dehumidification experiments at several yards and bases.

Disease inquiries.--A tally of inquiries shows 283 were handled in 1953, as compared with 233 in 1951, exclusive of special surveys.

BLISTER RUST CONTROL[3/]

Blister Rust Control operations are on a maintenance basis in Georgia, North Carolina, South Carolina and Tennessee. Only periodic re-examinations of control areas to keep abreast of ecologic changes and other factors that may adversely affect the current status of *Ribes*[4/] suppression in these states will be required. In Virginia and West Virginia, where *Ribes* are more generally found, suppression work must be continued on 313,000 acres, since the number of bushes occurring on this acreage has not been reduced to the maintenance standard.

Blister rust is being found in more and more isolated, unprotected areas in North Carolina and Tennessee. It is found generally in Virginia and West Virginia where *Ribes* grow in association with white pine.

The accelerated planting program in the Southern Appalachian States places increased responsibility on individuals and agencies where white pine is involved. These groups should make every effort to determine whether gooseberries or currants, both wild and cultivated, are growing within 900 feet of planting sites. Failure to take this precaution can result in complete loss of plantations of white pine if *Ribes* are present. Blister Rust Control personnel of the Bureau of Entomology and Plant Quarantine at Asheville, North Carolina, Pipestem, West Virginia, and Harrisonburg, Virginia, will gladly furnish information regarding *Ribes* distribution in the control area and make recommendations regarding questionable sites prior to planting.

3/ Report of the Division of Blister Rust Control, Bureau of Entomology and Plant Quarantine, in cooperation with the Southeastern Forest Experiment Station.

4/ Wild and cultivated currants and gooseberries, which are alternate host for white pine blister rust fungus.

FOREST INSECT CONDITIONS IN THE SOUTHEAST DURING 1952[5/]

The desire for more information on forest insect losses in the Southeast and methods of reducing these losses has demanded increased attention during the past few years. Foresters and woods workers in this area have been alerted through training sessions, correspondence and personal contact to watch for insect outbreaks. Report forms, mailing tubes and instructions pertaining to the collection of insects have been provided for reporting serious or unusual insect activity. All reports received by entomologists at this laboratory have been investigated and control methods recommended, when such were indicated or available. The increased number of reports of insect activity indicates that increased cooperation and coverage is being obtained each succeeding year.

Southern Pine Beetle

The southern pine beetle, Dendroctonus frontalis, outbreak in loblolly pine which occurred during 1951 in southeastern North Carolina has abated.

During 1952, reports of infestation were received and investigated from every State in the Southeast. An owner near Cheraw, South Carolina, lost about 10,000 board feet in May 1952, where infested trees were cut and burned. Loss of about 30,000 board feet of shortleaf pine in Leslie County, Kentucky, continued in 1952 but the infestation appeared to be declining. The principal control in Kentucky is apparently being effected by the pileated woodpecker. Supplementary control measures consisted of locating infested trees from the air and detailing crews to locate, cut and burn them. During August 1952, an infestation near Franklin, Virginia was investigated in which approximately 25,000 board feet of loblolly pine was killed. Infestations had built up slowly adjacent to lightning-struck pines and had not spread rapidly. All wood down to a 3-inch diameter limit was utilized and the bark burned. During this same month an attack on 5-10 acres of loblolly pine near Wilma, Florida, was investigated. Those trees which still contained broods were sprayed with 0.5 percent gamma benzene hexachloride in fuel oil. An attack on several hundred trees occurred in the Great Smoky Mountains National Park in September. Infested trees were cut and treated with orthodichlorobenzene in fuel oil. An infestation of about one-third acre was observed near Marion, North Carolina, in October, and about 60 acres containing approximately 300,000 board feet in 40 beetle-killed areas of shortleaf and Virginia pine were detected during this same month on the Tallulah Ranger District in Georgia. Salvage cutting with destruction of the slabs was recommended.

Black Turpentine Beetle

The black turpentine beetle, Dendroctonus terebrans, as in the previous two years continued to attack and kill a considerable volume of

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5/ Report of the Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine, in cooperation with the Southeastern Forest Experiment Station.

pine in northcentral and northeastern Florida. In northeastern Florida three general zones of infestation totaling 43,000 acres were located. Within these zones about 10,000 acres was estimated to have been attached rather severely, with some individual gum producers losing as high as 40 percent of the total number of stems in portions of their most heavily turpentined stands. In November it was determined that attacks decreased by 78 percent in the older centers of infestation during the latter half of the year. About 6,500,000 board feet was killed by Ips and the black turpentine beetle combined during 1952 in this area. Of this amount, about 5,000,000 board feet was salvaged.

In one area in northcentral Florida the attacks have continued unabated with little indication of any decrease in activity on about 9000 acres. The attacks are concentrated on about 4500 acres of slash pine in so-called pond areas. Trees in these areas were operated for naval stores until the present infestation started in 1950. Because of the aggressive nature of the infestation, the area is being clear cut, leaving seed trees. Three million board feet of the expected cut of about 13 million board feet is estimated to have been attacked during 1952 by the black turpentine beetle.

Ips Beetles

Infestations by Ips beetles continued to exact as heavy a toll of pine timber in 1952 as they did in 1951. The areas of severest attack occurred across northern Florida and southern Georgia, where it was common to observe mile after mile of dead and dying pines along the roads. Pines in the vicinity of pulp mills, as well as those affected by drought and fire, were especially susceptible to attack. In 1951 it was estimated that 126 million board feet of pine were killed on commercial forest lands by Ips in the Southern Region of the Forest Service. Of this amount about 60 million board feet was estimated to have been killed in the Southeastern States. An equal or greater amount is believed to have been killed during 1952. Due to the nature of attack, by this beetle, it is impossible to obtain accurate loss information figures. Attacks by this beetle are generally scattered over a few trees to the acre. The Southeast has approximately 62 million acres of commercial coniferous type subject to attack from Ips beetles.

The Pine Needle Aphid

An aphid-like insect, Pineus pinifoliae, of the family Chermidae, infested approximately 30,000 acres of eastern red spruce along the tops of the Southern Appalachians during May and June 1951. Adults of these insects flew to white pine, the alternate host, where they oviposited on the needles. When the eggs hatched, the crawlers attacked the new growth of white pine by piercing the twig with their mouth parts. Killing of the terminals of white pine in localized areas resulted. Observations were continued in 1952 to determine whether additional damage occurred in the spring when the crawlers resumed feeding. No additional damage was noted. Survival of the crawlers over the winter was estimated at less than one-tenth of one percent. Observations on damage to white pine were made in areas which were heavily attacked. Understory and

suppressed white pine were killed, while dominant, codominant and intermediate trees survived. In instances where trees were heavily attacked and survived, the lower branches were generally killed.

Nantucket Pine Moth

The Nantucket pine moth, Rhyacionia frustrana, continued to be a serious pest of loblolly pine plantations and reports indicated that damage was more severe in 1952 than in previous years. The entire lower Piedmont and upper Coastal Plain areas of Georgia, North Carolina and Virginia were seriously affected. One block of about 500 acres near Americus, Georgia, had practically every tip hit on trees from a few feet to 20 feet tall. In several cases R. rigidana has been found in association with R. frustrana. R. rigidana will attack tips of pine trees of practically any height.

Loopers

Defoliation of hardwoods, especially oak and hickory on about 14,000 acres in western North Carolina occurred in May 1952. Several species of loopers including Alsophila pometaria, Erannis tiliaria, and Phigalia titea (Geometridae) were found defoliating black locust, red gum, red maple, sourwood, and dogwood as well as oak and hickory. On heavily defoliated areas only the leaf midribs remained. Thirty-three areas of defoliation varying in size from 40 to 1900 acres were reported or observed. These were concentrated principally along the ridges south of the line separating Haywood from Jackson and Transylvania Counties. The defoliated trees put out a second set of leaves during the months of June and July.

Miscellaneous Forest Insects

A pine sawfly, Neodiprion americanus, was reported in February 1952 as causing severe defoliation to pond, longleaf, and slash pine near Folkston, Georgia. Investigation revealed that about 10 acres of pine had been defoliated. Heaviest defoliation occurred on pond pine which in many cases were completely stripped of needles. By early April the buds had burst and the trees were putting out new needle growth.

Early in June this same species was reported as causing severe defoliation to loblolly pine along the coast of Virginia. Loblolly pine 35-55 feet tall were being stripped of their old needles by this sawfly. The new foliage which had been put out by the trees during 1952 was not attacked. Areas of infestation in Virginia varying in size from 1 to 5 acres were reported from Ware Neck, west of Mobjack, east of Mathews, Gwynn Island, northeast of Heathsville, west of Lewisetta and near Cole Point.

The locust leaf miner, Chalepus dorsalis, in 1952 again caused severe browning and defoliation of the foliage of black locust throughout the Southern Appalachians. Browning of foliage was observed in eastern Tennessee and Kentucky during the early part of July. Browning of leaves in western North Carolina was not common until the early part of August. This defoliation is not considered serious.

The mimosa webworm, Homadaula albizziae, continued to cause severe defoliation of honey locust and mimosa in several localities in North Carolina. It was also reported as causing heavy defoliation in several localities in South Carolina.

The pin oak sawfly, Caliroa lineata, which was reported as being present in the State of North Carolina in 1951 for the first time, did not increase during 1952.

About 250 acres of turkey oak were completely defoliated in Bladen County, North Carolina in September by the variable oak leaf caterpillar, Heterocampa manteo. Heavy defoliation of blackjack oak in Aiken and Lexington Counties, South Carolina was also reported. This species often causes sporadic outbreaks in the hardwood forests.

The gregarious oak leaf miner, Cameraria cincinnatiella, became abundant in Gaston County, North Carolina in August on chestnut, red and post oaks.

Numerous reports were received of injuries caused by adult feeding of borers and weevils. In some cases reproduction had been killed by the Pales Weevil, Hylobius pales, while in other cases scarring or deformation injury had been caused by feeding of round-headed borers (Cerambycidae), and flat-headed borers (Buprestidae). Early feeding by adult borers on buds of slash pine before they opened in April on a 100 acre tract in Florida caused the elongating new growth to twist into a complete circle in some instances.

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by

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Agriculture-Asheville

STATION PAPER NO. 23

APRIL 1953

The Development of an Automatic Wood-Burning Furnace for Curing Bright-Leaf Tobacco

A Progress Report

by

Walton R. Smith, R. H. P. Miller,

O. A. Brown, & N. W. Weldon

SOUTHEASTERN FOREST EXPERIMENT STATION

Asheville, North Carolina

E. L. Demmon,

Director

U. S. Department of Agriculture - Forest Service

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Appendix A - Furnace construction, course by course

Appendix B - Cast iron parts and metal work

Appendix C - Some suggestions about wood for the furnace

SUPPLEMENT TO STATION PAPER NO. 23

During the construction of automatic wood-burning furnaces in the summer of 1953, it was found that the over-all size of the furnace varies slightly as constructed by different brick masons. Thus, the size of the opening cut in the barn to receive the furnace, as described on page 10 of the report, is sometimes not large enough to give the required distance of 8 inches between the furnace and adjoining wood parts as specified on page 15. It is absolutely necessary to have this 8 inches of masonry between the furnace and wood framing. Barn fires have occurred where this precaution was not observed.

A good way to avoid this difficulty is to have a large opening in the barn to receive the furnace. It should probably be at least 5-1/2 feet square. After the furnace is completed, 8-inch cement or cinder blocks can be used around the furnace to separate it from the wood framing. The permanent wood framing can then be installed after the furnace has been completed. The hollows in the cement blocks should run parallel to the length of the furnace and they should be filled with insulating material or mortar to prevent air leakage into the barn.

Some attempts have been made to modify the design of the furnace to permit using longer fuelwood or to simplify construction. Since many various designs were attempted and the present one found best, it is inadvisable to make such changes.

Some difficulty has been encountered in the use of the solenoids that control the draft door. As they come from the factory these solenoids consist of two parts, one the field or coil, and the other the plunger. If the plunger drops out of the coil, the bottom corners of the coil should be slightly crimped to retain the plunger and keep it from falling out. This is very simple to do and essential when the solenoid is connected to the upper hole in the linkage, as is necessary in temperatures above 130°F. (See page 17).

THE DEVELOPMENT OF AN AUTOMATIC WOOD-BURNING FURNACE FOR CURING BRIGHT-LEAF TOBACCO

A Progress Report

by

Walton R. Smith, R. H. P. Miller, O. A. Brown, and N. W. Weldon[1/]

Introduction

Wood, the first fuel used to cure bright-leaf tobacco, is fast losing its importance for this purpose. While extensive research has been done on coal stokers, oil burners, automatic controls, and various types of heating equipment, very little work has been done to improve the efficiency of wood-burning furnaces for this purpose or to develop automatic controls for wood-burning furnaces. Some years ago, the Forest Utilization Service of the Southeastern Forest Experiment Station, the Forest Products Laboratory, and the Bureau of Plant Industry, Soils, and Agricultural Engineering, Division of Farm Electrification, established cooperative studies with the North Carolina Agricultural Experiment Station to conduct research on wood-burning furnaces for tobacco barns at the Tobacco Experiment Station, Oxford, North Carolina. This work has been going on since 1945 and has resulted in an entirely new type of automatic, wood-burning furnace that cures tobacco satisfactorily and at the same time saves wood and labor.

Farmers as well as foresters are interested in wood as a fuel because it offers an outlet for cull trees, limbs and tops, and various other forms of wood waste that should be removed from the woodlot. Using wood for fuel gives the farmer a chance to improve forest stands by thinnings or improvement cuttings for a profit, rather than as a management cost.

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In the bright-leaf tobacco belt from Virginia to Florida, there are more than a quarter million tobacco barns; some are used for as many as six cures of tobacco each summer. From the best estimates that can be obtained, each tobacco cure with a wood furnace requires from 1-1/2 to 2 cords of wood. Since wood was the fuel used in more than 80 percent of the tobacco barns in the early 40's, about 2 million cords of wood were used annually for this purpose.

Up to the present time the typical wood furnace in a tobacco barn has been little more than an open fireplace (figures 1 and 2). Actually it is either one or two fire chambers, each about 18 inches wide, 18 inches high, and 8 feet long, extending inside the barn. Large flue pipes 10 to 12 inches in diameter extending from the furnace to the far side of the barn make a U turn and leave the barn just over the furnace to form a chimney which may stop within a few feet or extend above the roof. There are numerous variations of this set-up but the principle is the same. The furnace has no draft control and the amount of heat supplied to the barn depends on a man's continuous attention to the fire; he can put on more fuel to make it hotter, or pull the fire out of the furnace if the temperature gets too high. This takes a great deal of his time night and day for the 5 days of a tobacco cure.

Since existing wood-burning furnaces require so much of the farmer's time, it is little wonder that coal stokers and oil burners with automatic control and large hopper capacity have become so popular. Tobacco farmers have been changing over to the use of these fuels very rapidly; in fact, it is currently estimated that less than half of the tobacco barns are now fired by wood. Oil burners are becoming predominant because of the lower cost of installation and the ease of operation, in spite of the high annual fuel cost.

Figure 1.--The single type wood-burning furnace in common use.

Figure 2.--The double type wood-burning furnace in common use. Constant attention to the fire is required.

Review of Experimental Work

The first experimental work was done at the Tobacco Experiment Station at Oxford, North Carolina, during the summer of 1945. It was learned that some attempts had been made to burn wood efficiently in the old-type furnaces of tobacco barns by putting a tight door on the front of the furnace with smaller draft openings that could be automatically controlled. One manufacturer had developed a plan for putting a tight-fitting door on the end of the furnace, supplemented by an L-shaped sheet metal pipe which permitted air to enter the side of the furnace (fig. 3). This air-inlet pipe extended about 4 feet above the ground level of the furnace, and had a damper in the top of it to control the amount of entering air. The damper was operated by a wafer thermostat placed inside the barn.

Two barns of tobacco were cured with this equipment, using 1.15 cords of half green sweetgum per cure. The biggest disadvantage of this furnace was its failure to hold a high temperature for any length of time without refueling. At most, only about 200 pounds of wood could be put into the furnace at one time and this would burn up in two or three hours when high temperatures were needed.

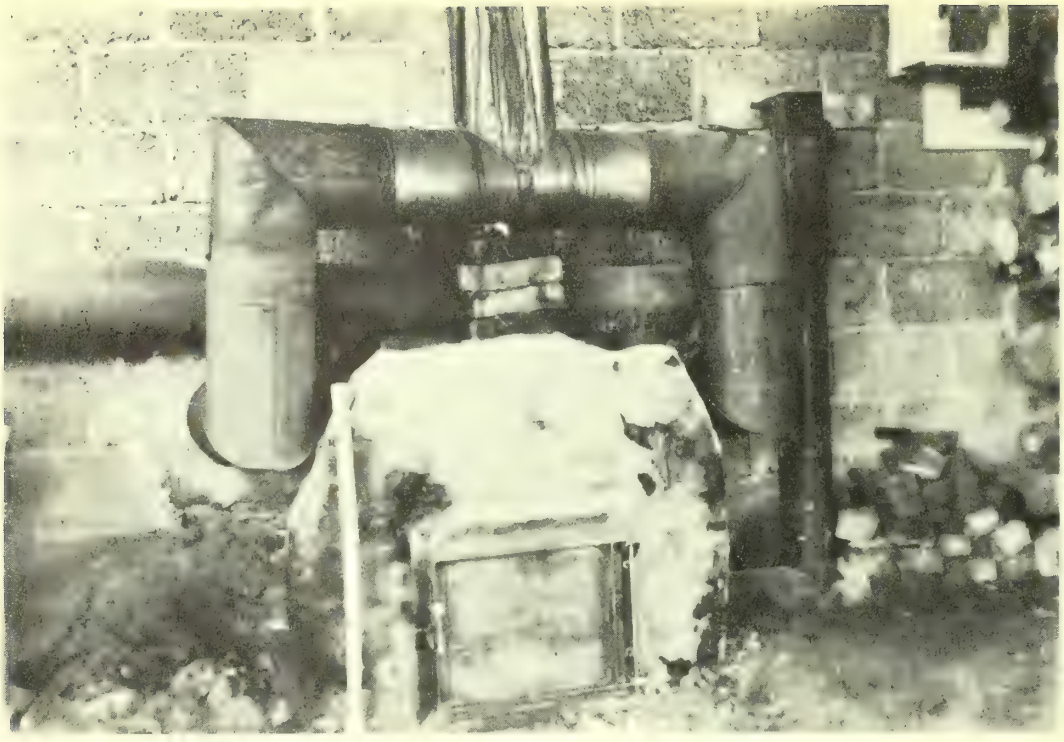


Figure 3.--The first experiment was to operate an old type furnace with a tight door and draft controls on the L shaped air inlet.

The tests made in the summer of 1945 showed that tight doors and simple draft controls on the old open wood furnace will reduce the amount of wood needed to cure a barn of tobacco and will give some temperature control of the barn so that one person need not watch the fire continually. However, this furnace held so little wood that it would burn only for a few hours; it still required more of the farmer's time than a coal stoker or an oil burner. Thus, an entirely new and different type of furnace was planned for the 1946 tobacco-curing season.

The new furnace, designed by the Forest Products Laboratory, was built on a barn at the Tobacco Experiment Station in June, 1946. This furnace was strictly an experimental model to determine whether a large hopper type of furnace could be used which would give continuous high temperatures for 6 to 8 hours.

The 1946 furnace was successful through six cures, using 1.2 cords of oak wood per cure, and conclusively proved that the principle of slow combustion for long periods could be applied in an automatic wood furnace for tobacco barns. Details of furnace construction and temperature control needed further study but the 1946 furnace established the principles that have been used in all subsequent furnaces.

The new furnace was constructed in two main parts--a large hopper or primary combustion chamber on the outside of the barn and a secondary combustion chamber on the inside (fig. 4). This secondary combustion chamber is very much like the old-type wood furnace that extends inside the barn. The entire furnace was built of a single thickness of fire-

brick. On the ground level there was an ash pit about 6 to 8 inches high; above this were grates built of firebricks with four grate openings, merely spaces between the rows of firebricks. Above the grates was the hopper, which extended to the top of the furnace and was large enough to hold about 900 pounds of oak wood. The floor of the hopper sloped on the front side of the furnace so that the firewood rolled to the back, where most of the burning took place. A draft control opening and an ash pit door were on the front of the furnace at the bottom and permitted the entrance of air through the grates and allowed for the removal of ashes. Secondary air inlet pipes on each side of the furnace were about 2 inches in diameter and permitted a continuous flow of air into the secondary combustion chamber. Wood was put in the two side doors, there being no opening in the top of the furnace. In this type of furnace, practically all burning took place in the hopper just over the grate. Air entering the draft control door was preheated to some degree by the sloping brick wall before it passed through the grates where it supported combustion in the lower portion of the hopper. The gases then passed into the secondary combustion chamber, where further burning took place due to additional secondary air supplied. No wood went into the secondary combustion chamber. The gases convected the heat into the flues in the tobacco barn, and the heat was radiated and conducted through the air in the tobacco barn to raise the temperature.

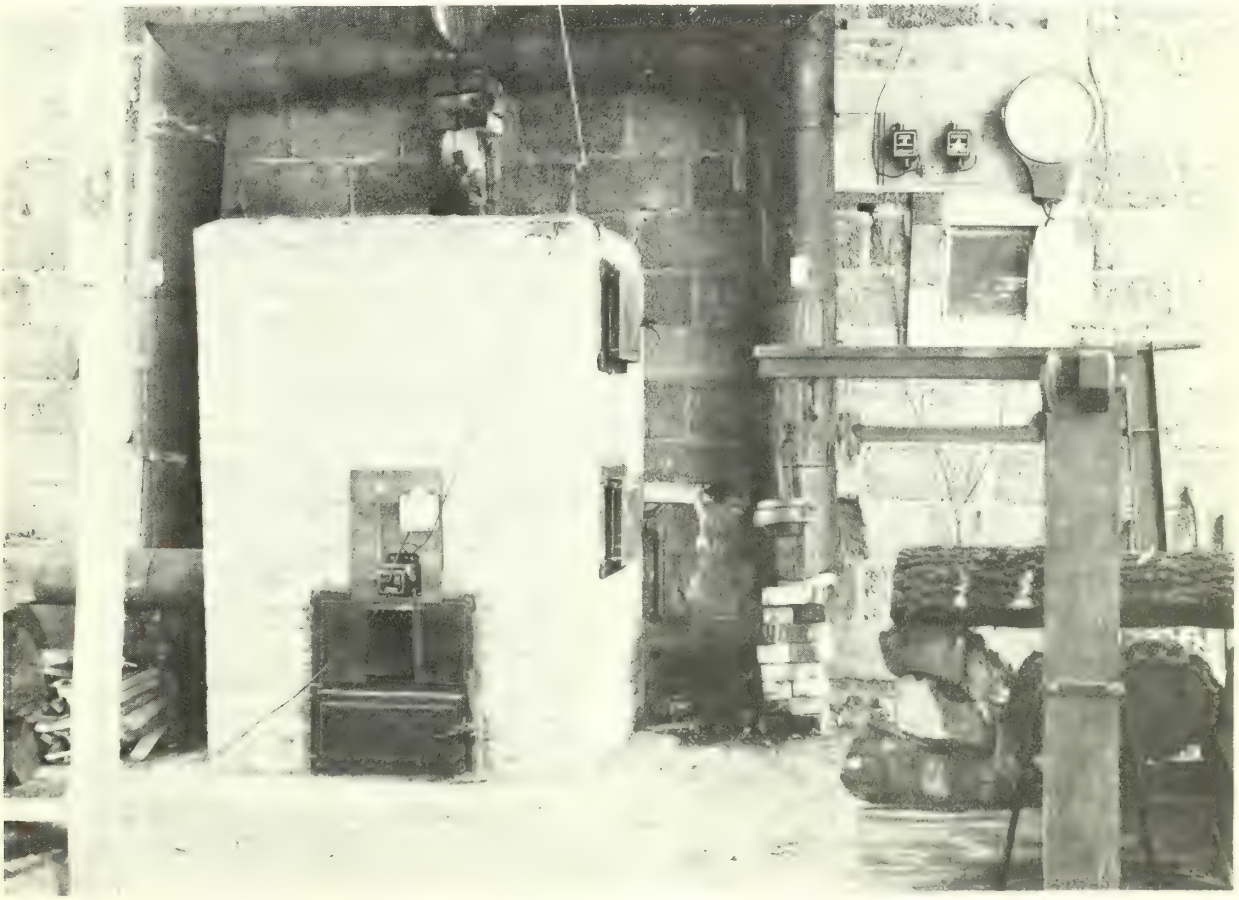


Figure 4.--The 1946 model, only one brick thick and largely outside the barn, was built to establish the principle of slow combustion in a large unit.

Temperature control on this furnace was obtained by use of a thermostat in the barn, which in turn operated a damper motor to open or close the draft control door as necessary to give the desired amount of heat.

Although establishing a principle, the 1946 furnace was too inefficient because it was outside the barn and only one brick thick.

In 1947, a furnace was constructed with most of the unit inside the barn, with the refueling door on the front of the furnace. The furnace construction was quite similar to the 1946 model except that the inside furnace wall was made of firebrick with refractory precase slabs over the arches and the outside wall made with common brick, the two walls being mortared together (fig. 5). Standard thermostat controls operated a draft motor which opened the draft door when the barn called for heat. Two cures made in 1947 used less than a cord of wood each. The furnace operated satisfactorily and gave long periods of burning without attention. The next step was to test it on farms and to see whether it was a durable structure.

In 1948, similar furnaces were built on two private farms and operated under farm conditions (figures 6 and 7); additional cures were also made with the furnace at Oxford. All cures made with these furnaces were satisfactory and the two furnaces on private farms have continued to operate satisfactorily until the last time inspected in 1952. Some objectionable features, however, were discovered during the second year of operation.

Figure 5.--The 1947 furnace, with its refueling door on front, was of double wall thickness and largely inside the barn.

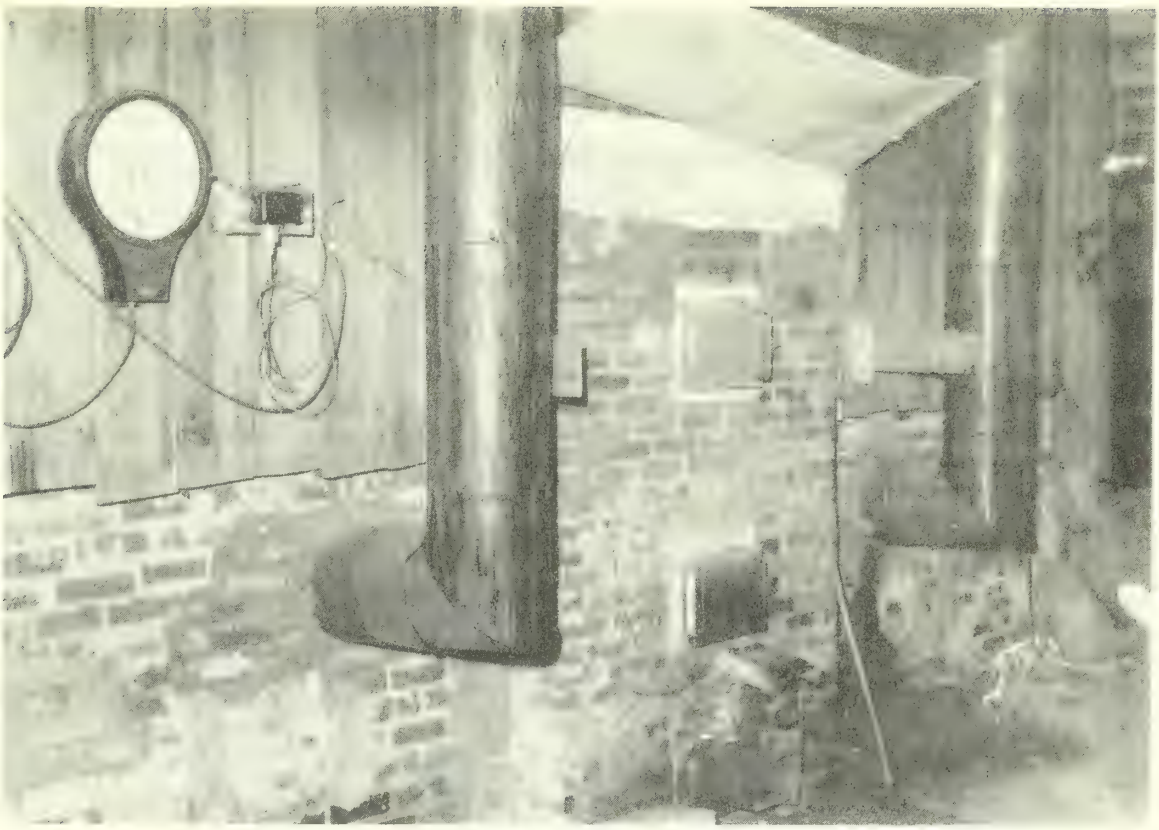


Figure 6.--A straight-walled furnace was built on a private farm in 1948.

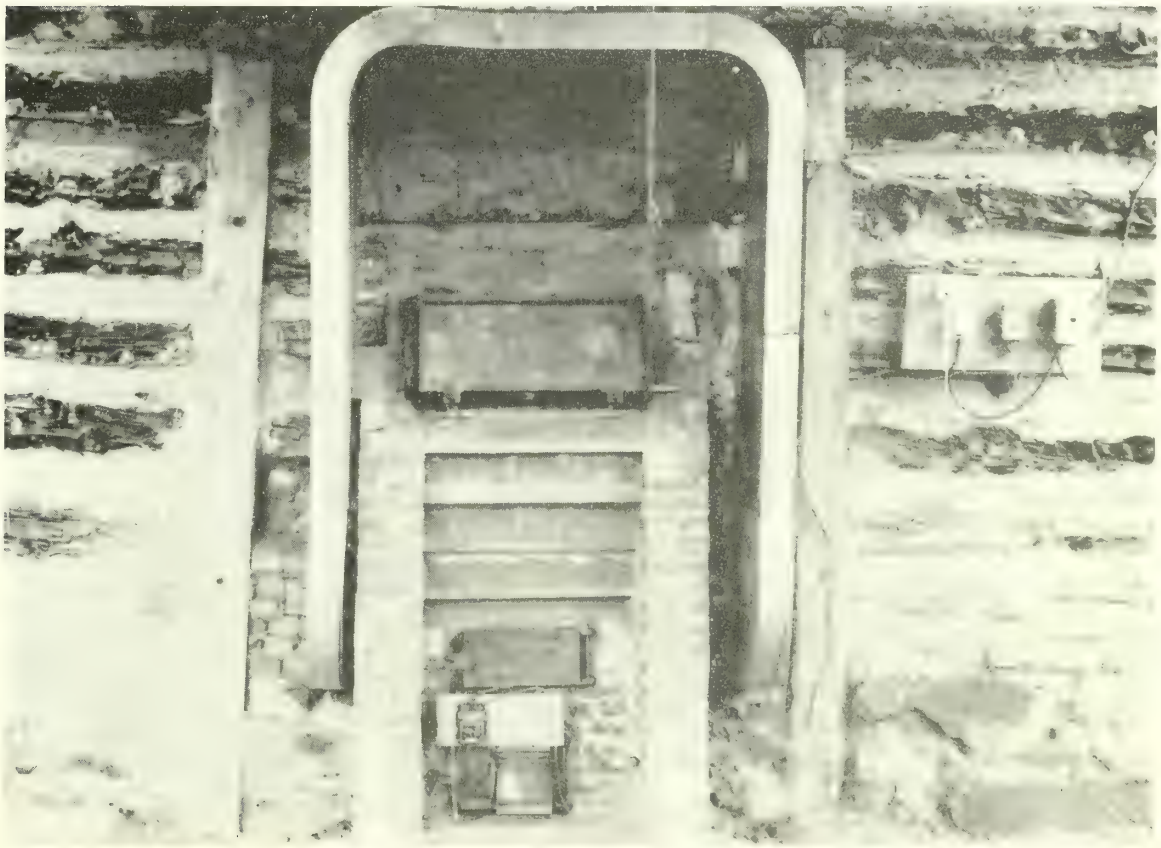


Figure 7.--A furnace almost identical with the 1947 model was built on a private farm in 1948. Note rectagular aluminum flues. This furnace operated for several successful cures in 1952.

The large mass of brickwork developed cracks under the severe temperature conditions prevailing in the furnaces. Sometimes these cracks would permit extra air to enter the primary combustion chamber and thereby raise barn temperatures higher than the thermostat settings. These cracks were mortared up after each run, and the bad effects were not serious (fig. 8).

Another disadvantage of the 1948 furnace, and any similar natural draft furnace with two separate flues leading from the furnace, was the heat distribution in the flue system. Whenever one flue became hotter than the other, it would take most of the heat from the furnace, leaving the opposite flue relatively cold. The use of dampers in the flues did not materially change this situation, although the operator could switch the heat back and forth. The net result was uneven temperatures inside the tobacco barn.

Subsequent observations have shown that this condition prevails in most tobacco barns with nearly any type of natural draft furnace, but the operators are seldom aware of this temperature difference, as they operate with only one thermometer in the barn. Nevertheless, the research objective was to produce an automatic wood-buring furnace that would give uniform barn temperatures and long periods of burning, so further development was needed.

In 1949 an experimental furnace was constructed with a dividing wall separating the furnace into two parts except at the fuel door. Here, wood was pushed in on the dividing wall and then turned left or right to fill the hoppers of the two furnaces. The secondary combustion chambers and the flue systems and stacks were completely separate for each furnace.

In operation this furnace performed like the single-type furnace, and when one flue became hot, it drew all the heat from the fire in the other furnace over the partitioning wall. This furnace was abandoned when it became clear that two entirely separate furnaces were necessary to maintain uniform temperatures throughout the barn.

During the same year, two separate and smaller furnaces were constructed in one barn (fig. 9). These furnaces were simplified and constructed with metal grates and doors, vertical walls throughout, and standard refractory slabs to cover the arches. One furnace had the inner firebrick and outer common brick walls mortared together and the other furnace had a 2-inch space between these walls which was filled with a vermiculite insulation material. Each furnace had its own thermostatic control and flue system. Instead of operating the draft doors with a motor, a 1/2-inch-stroke electric solenoid was used on each draft door.

Very satisfactory results were obtained with this dual-type automatic furnace and all the research objectives were met. The insulated furnace stood up better under the intense furnace heat; also, a few other minor refinements and operational details were discovered.

In 1950, the dual-type automatic furnace was partly rebuilt to add the refinements and it was again operated satisfactorily during the curing

Figure 8.--Cracks sometimes developed in brickwork near thimbles or doors and required re-mortaring occasionally.

Figure 9.--The 1949 model dual type automatic wood-burning furnace.

season. A time temperature chart of cure No. 3, 1950, is shown in figure 10. One of the remaining steps necessary before recommending it widely to the tobacco farmer was continued testing for furnace durability and farmer operation. To this end additional cures were made with this furnace in 1951 and 1952.

Also in 1952, two furnaces of this type were constructed on private farms according to plans and supervision furnished by the Forest Service. Farmers operating these furnaces liked the ease of operation and low fuel consumption. Depending on the size of the barn and the quantity and condition of the tobacco, the furnaces cure a barn of tobacco with from 3/4 to 1-1/4 cords of wood.

Although this furnace has passed through the experimental stage satisfactorily, it needs to go through the pilot stage in which it would be operated by farmers under farm conditions for several years. Upon the elimination of difficulties which appear in subsequent trials on farms, the unit may be expected to find a place in commerical tobacco production. For the benefit of farmers who are willing to assume the risk of a new-type furnace, complete instructions, including bill of materials and approximate cost are given.

Construction of the Dual-Type Automatic Wood-Burning Furnace

Since the automatic wood-burning furnace is not a cheap installation, it should be built only on a good tight barn with roof ventilators that will control the amount of air passing through the barn.

The first job is to cut two holes in the end of the barn for the furnaces. These holes should be flush with the sides. The finished openings 50 inches wide and 54 inches high should be framed with two 2 x 4's on each side and two 2 x 6's on edge over the top. The foundation or footings of the barn must also be cut out to allow for the foundations of the furnaces (fig. 11).

The slab for the furnace should be 5 inches thick, 46 inches wide, and 82 inches long; it should be 6 to 12 inches inside the side wall, and extend 6 inches beyond the end wall (notice furnace position in figure 12). Where the soil is porous and sandy and drainage is no problem, the top of the slab should be 6 to 8 inches below ground level; otherwise the top of the slab should be kept as low as possible, maintaining drainage. A lumber form should be used for the slab and the ash pit. After the forms are lined up in their proper places and leveled, they should be nailed to stakes to hold them in place. The concrete, made from 1 part cement, 2 parts sand, and 3 parts of gravel, should be troweled smooth and allowed to harden before the forms are removed and the brickwork started (fig. 13).

The furnace consists of a double wall construction with insulating concrete between the inner and outer walls. In general, the inner wall is of pressed firebrick which should be uniform in dimension for thin dipped joints, and the outer wall is of common brick.

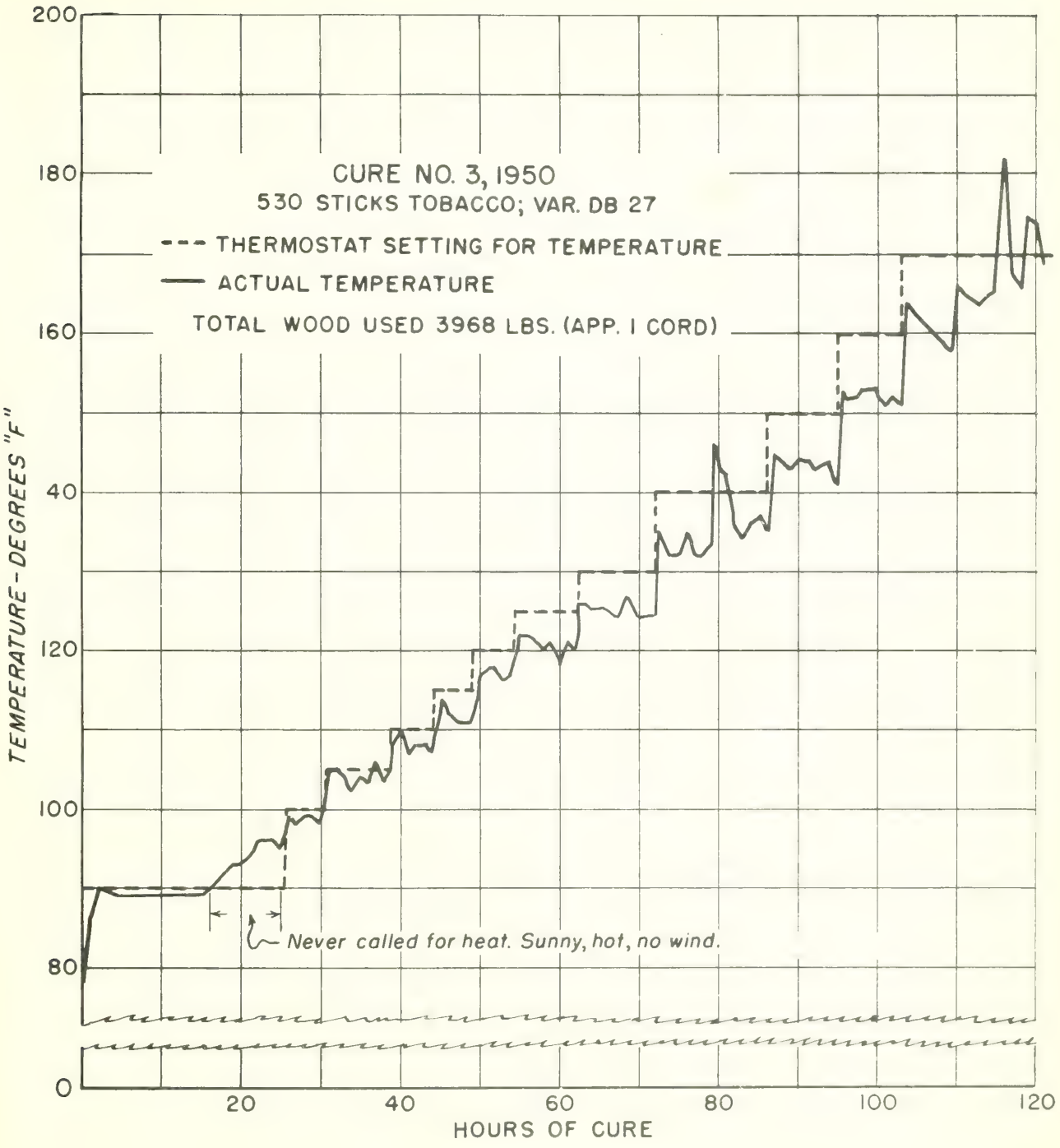


Figure 10.--A time temperature chart for the dual-type automatic wood-burning furnace shows good control. This cure used 3968 pounds of wood (approx. 1 cord).

Figure 11.--Tobacco barn under construction. Two openings in the end of the barn have been cut and framed for the furnaces.

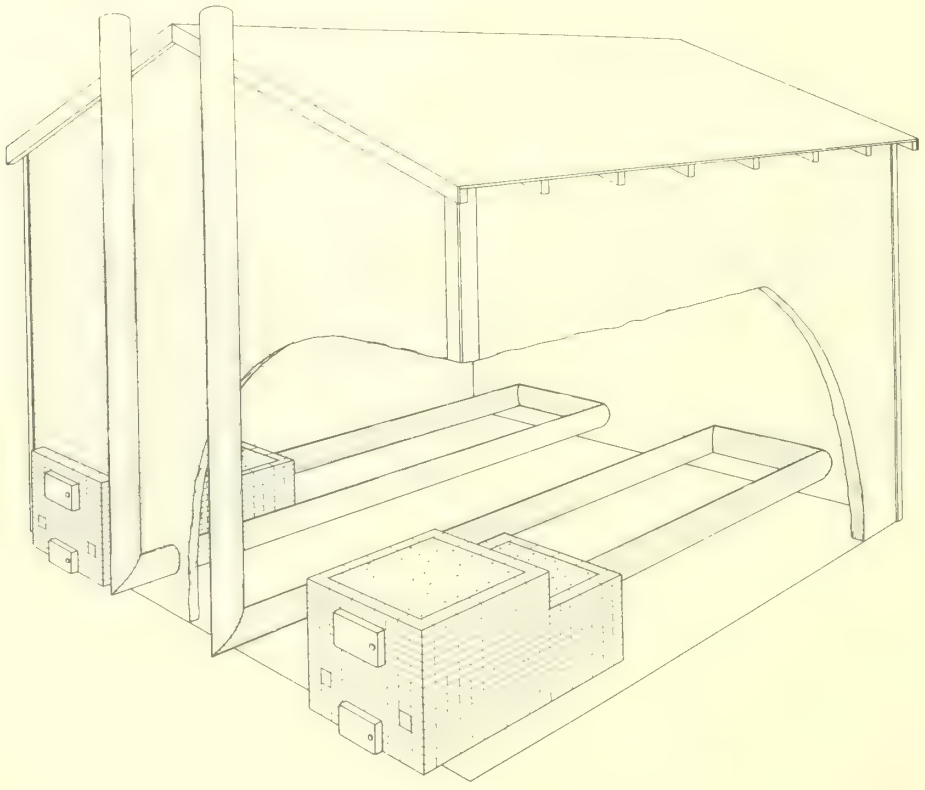


Figure 12.--A cut-away view showing the position of the furnace and flue system with respect to the barn.

Figure 13.--Pouring the concrete slab in the wood form.

Complete drawings of the furnace construction, course by course, are given in Appendix A. These drawings should be followed carefully, especially the dimensions given for the inside walls. The drawings are for the left furnace. This is to have the flue leaving the furnace near to the barn wall to prevent cold down drafts. The right furnace would be constructed with the flue exit offset on the other side.

Careful attention should be given to laying the firebrick. A high temperature refractory cement such as "Setskold" should be used for the firebrick joints. These cements are usually contained in a metal drum and should be mixed in this drum thoroughly before use. A small amount of it is placed in a flat pan; usually it is necessary to thin it with water; and then the firebrick are dipped so that a layer about 1/16 inch thick adheres to the brick. Naturally the cement must be kept clean from brick chips, etc., if thin joints are to be made. When not being used, the refractory cement should be covered to prevent lumping.

For laying the common brick, use a mixture of 1 part brick mortar and 3 parts of good sand (field sand is not usually satisfactory under high temperature use). The mortar is applied with a trowel, with joints averaging about 1/2 inch in thickness. The courses of firebrick and common brick must be kept level.

The inner wall can be laid up to and including course 7 before the outer wall of common brick is started. On top of course 2, the lintel for the ash pit door opening must be put in place, the grates on top of course 3 and the thimble on top of course 4 (figures 14 and 15). Sand should be

put in the secondary combustion chamber up to the top of the fourth course of brick. The first four courses of the outer wall can then be completed with the ash pit door frame in place.

The door frames and the flue thimbles should have three layers of wrapping paper on them when they are placed in the wall. This paper will burn away and allow for the difference in expansion between metal and brick. The door frames have threaded holes for the anchor hooks which are mortared in between the two walls.

After the fourth outside layer of brick have been put down, it is time to begin filling the space between the brick walls with insulating cement. Any good vermiculite aggregate (locally sold as Zonolite) is suitable. It should be mixed 5 parts of the vermiculite, 1 part of Portland cement, and 2-1/2 parts of water. Mix the cement and water first and then add the vermiculite. Even though the mix may seem a little dry, it will serve adequately as a filler. The insulating concrete should not be tamped down, but just pressed and dressed down to the top of course 4 with a trowel so that the secondary air ducts can be put in place.

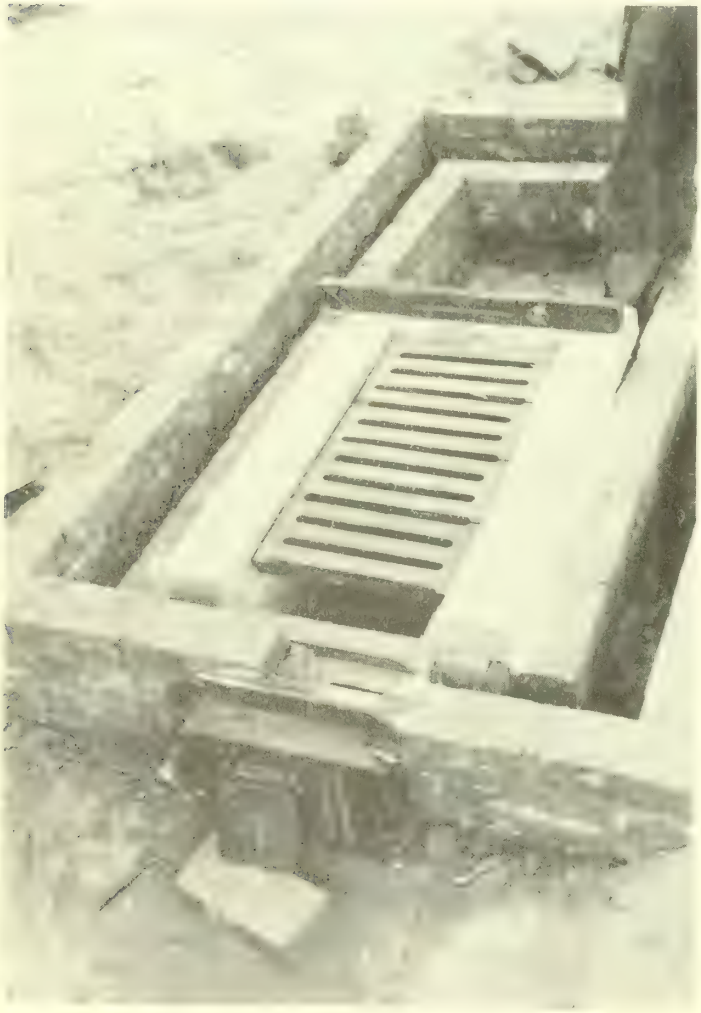


Figure 14.--The lintel for the ash pit door is placed on course 2 and the grates on top course 3.

Figure 15.--After course 4, insulating cement is used to fill spaces between walls, the secondary combustion chamber is filled with sand, and the secondary air ducts are installed.

The outside wall can now be continued up to the eighth course of bricks. After that, the inner wall can be completed. The tenth course of firebricks is put on edge (requiring a number of bricks to be broken in half) in the hopper and at the archway as shown in the drawing of course 10, Appendix A. In the secondary combustion chamber the bricks are laid flat (fig. 16). After course 10 has become firm, the slabs over the secondary combustion chamber can be put in place. More insulating cement can now be added to fill up to the top of course 7 before the work is continued on the outer wall to course 11. More insulating cement is added until it reaches the top of course 11. The fuel-door frame with the cast-iron metal slide is then put in place with a thin cement joint under the frame (fig. 17), and the outer brickwork is continued to course 16. The four hooked screws are mortared in place, and the opening on the sides and top between the outer and inner walls is sealed off with loose brick so that more insulating cement can be added. The slabs over the hopper are now set in place, and the outer wall completed and insulating concrete added and troweled even with the top of the outer wall on both the combustion and hopper sections. Finally, the space between the furnace and the wood wall (opening frame) should be filled with brick or concrete blocks as a safety precaution. Exposed wood should be at least 8 inches from the furnace.

The flues with the hopper type of furnace must be given more slope than with the old type of wood-burning furnace. Where the flues leave the barn they should be at least 10 to 12 inches higher than where they leave

Figure 16.--In the 10th course, half firebricks on edge are used for the inner wall of the primary combustion chamber. (Note: The thimble shown in this photograph is a substitute L flue to form the opening, since the regular straight thimble had not been obtained.

Figure 17.--The fuel door frame, with wrapping paper around it, is cemented in on top of course 11. Notice the metal slide cemented across the brick and under the door frame.

the furnace. Each furnace has its own stack extending above the ridge of the barn. Each stack should have a loose-fitting damper that can be locked in the closed and open positions.

After the furnace has been allowed to stand for several days, a low fire can be built in it to help dry out the unit. The furnace should not carry a hot fire for several weeks, in order to allow the mortar to cure and develop stronger joints.

Operation of the Furnace

The operation of the automatic wood-burning furnace can be dangerous or even unsuccessful if the operator does not understand the procedure. IT IS VERY IMPORTANT THAT THIS SECTION OF THE REPORT BE STUDIED BEFORE THE FURNACE IS OPERATED. The following instructions are very important.

CAUTION: THE DOORS OF THE FURNACE SHOULD NOT BE OPENED EXCEPT WHEN REFUELING BECAUSE:

1. ENTERING AIR CONTAINING OXYGEN WILL IGNITE THE WOOD GASES AND EXPLODE FLAME OUT THE FUEL DOOR. SEE INSTRUCTIONS FOR REFUELING.

2. THE UNCONTROLLED ADDITION OF AIR THROUGH THE FUEL DOOR WILL RAISE THE BARN TEMPERATURE HIGHER THAN THE THERMOSTAT SETTING.

Starting the Fire

Open the ash pit and fuel doors wide. Put paper and kindling wood on top of the grates. Put lighted paper under grates. Leave both doors open until good fire is started. Be sure that flue dampers are open.

Close fuel door and let kindling fire continue until flues are warm and drawing properly.

Open fuel door and fill hopper about half full of wood.

Check thermostats and solenoids to see that they are working properly, set thermostats at 90°F., and close all doors tightly. The solenoid connecting link should be set in the bottom hole for temperatures under 130°F.

The furnace should now hold the temperature at 90°F., for at least 5 or 6 hours.

Refueling at Low Temperatures (90°F. to 110°F.)

When the solenoids keep the draft door open almost constantly, it is an indication that the fuel supply is low. Open the fuel door and stand away from it for a moment. Then inspect the amount of wood and charcoal in the furnace and spread it evenly over the grates with a poker if necessary. Close the fuel door.

Close the dampers in the flues. Turn the thermostat back until the draft door closes. Allow to remain in this position for 5 to 10 minutes while wood is being stacked next to the furnace for refueling. During low temperature stages, use small, crooked, and doty wood if necessary and save the straight, larger pieces for higher temperatures.

Set the thermostat so that draft door again opens. Open the dampers. This is to help prevent flare-back when fuel door is opened.

Open the fuel door and load the wood up to the bottom of the fuel door but not above. Close the fuel door, reset the thermostat to desired temperature. Watch barn temperature for about 10 minutes to see that it does not exceed desired temperature.

Refueling at High Temperatures (110°F. to 170°F.)

When refueling at high temperatures, the same precautions are used as in low temperatures, but the furnace will be much hotter, and care must be taken to do the job quickly and correctly.

It is important not to refuel at high temperatures until necessary. Wait until most of the fuel in the furnace has been consumed and the draft door stays open continuously calling for heat. Usually, this means that the barn temperature will drop 10 to 15 degrees below the thermostat setting, but this will not cause any damage to the tobacco during the higher temperature stages.

Be sure to:

1. Close all doors and dampers 10 minutes before refueling.

2. Have enough large straight wood ready at furnace.

3. Use leather or asbestos gauntlet gloves to prevent burning hands.

4. Have an assistant if possible and use loading device. See figure 18.

5. Open dampers during loading but close immediately after furnace is loaded.

6. Do not reset thermostat or open dampers until 10 minutes after loading.

After a little experience, the operator will learn just about how much wood the furnace consumes in a 3- or 4-hour period during the different stages of curing. He will then arrange to check and load the furnace at breakfast-time, the lunch hour, at suppertime, and at bedtime. These are the times when he ordinarily inspects the tobacco.

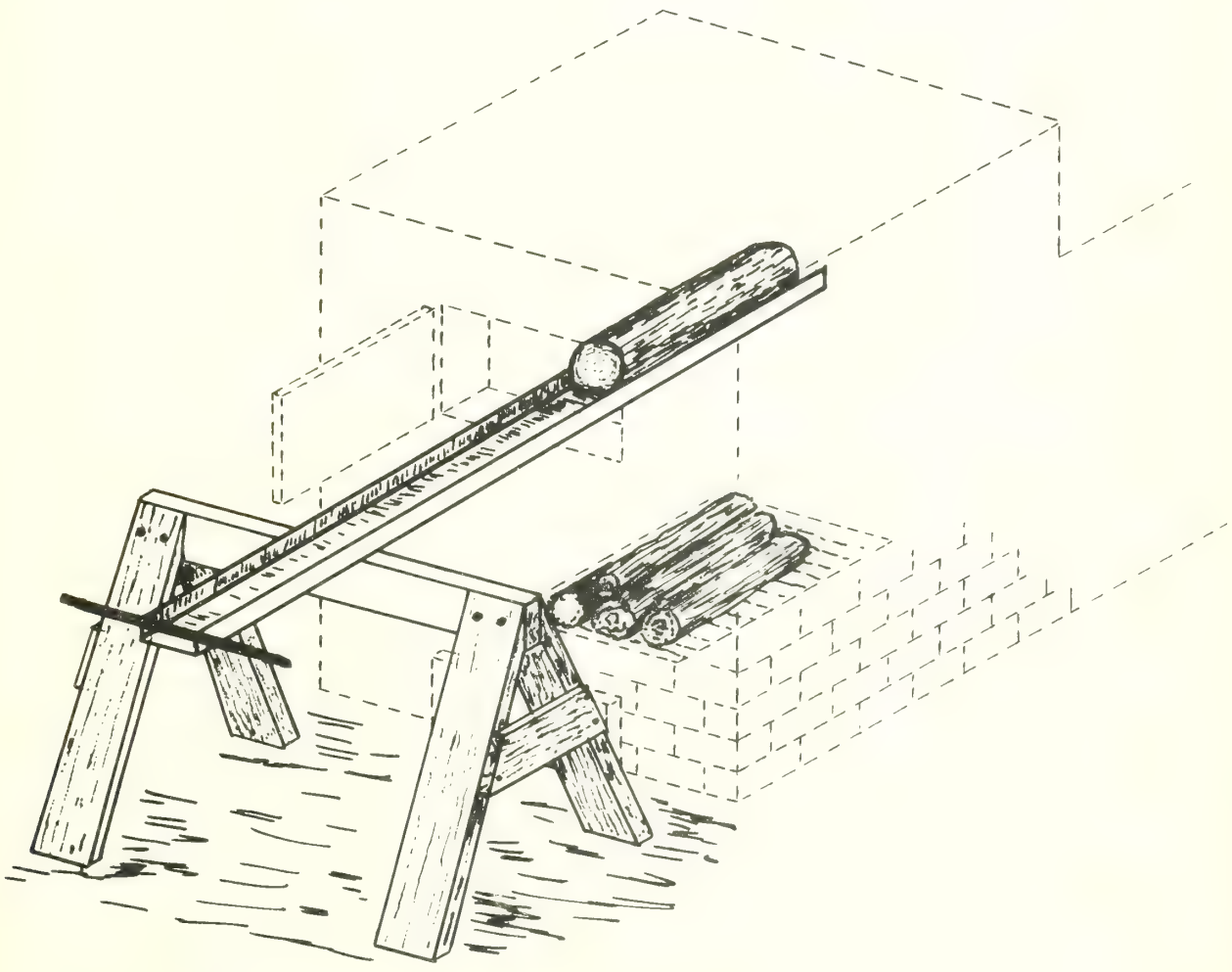


Figure 18.--Round wood is pushed into furnace on a light, 3-inch or 4-inch channel iron. A quick turn of the channel iron with the handle drops the wood to the grates. The handle is a 1-inch iron bar 18 inches long welded to the end of the channel iron.

Cost of the Furnace[2/]

Bill of Material and Approximate Cost (1952)

	Cost	
Masonry Material		
10 firebrick slabs 3" by 12" by 30" @ $5.00	$ 50.00	
530 firebricks 2-1/2" by 4-1/2" by 9" @ $0.13	68.90	
1150 common bricks @ $32.00 per M	36.80	
6 bags of brick mortar @ $1.10	6.60	
11 bags of Portland cement @ $1.30	14.30	
130 pounds of high temperature refractory cement (Setskold or equivalent)	7.60	
8 bags of vermiculite (for concrete aggregate) (Zonolite, etc.)	10.80	
1-1/2 cubic yards of sand	2.50	
3/4 cubic yards of gravel	2.00	$199.50
Cast Iron Parts		
8 cast iron grates @ $2.00 each	16.00	
2 fuel door units @ $14.50 each	29.00	
2 ash pit door units @ $14.50 each	29.00	
2 lintels for ash pit opening	4.00	
2 slides for fuel door opening	2.00	80.00
Metal Work		
4 secondary air ducts @ $7.50 each	30.00	
2 flue outlets @ $2.50 each	5.00	35.00
Controls		
2 thermostats[3/]	33.00	
2 solenoids[4/]	20.00	53.00
Labor (mason and helper) based on actual cost at 2 installations	118.26	118.26
Total Cost		485.76[5/]

2/ The costs given are based on actual costs of constructing several furnaces. S. L. Adams Co., Rowland, N. C., is planning to stock all parts for the furnace and the latest costs can be obtained by writing this Company direct.

3/ Thermostats can be purchased from United Electric Control, A & Athena Streets, Boston, Mass.

4/ The Solenoids (16 KKK, 100A, 1/2" stroke) can be purchased from the Electrical Mfg. Division, National Acme Company, 170 E. 131st Street, Cleveland, Ohio.

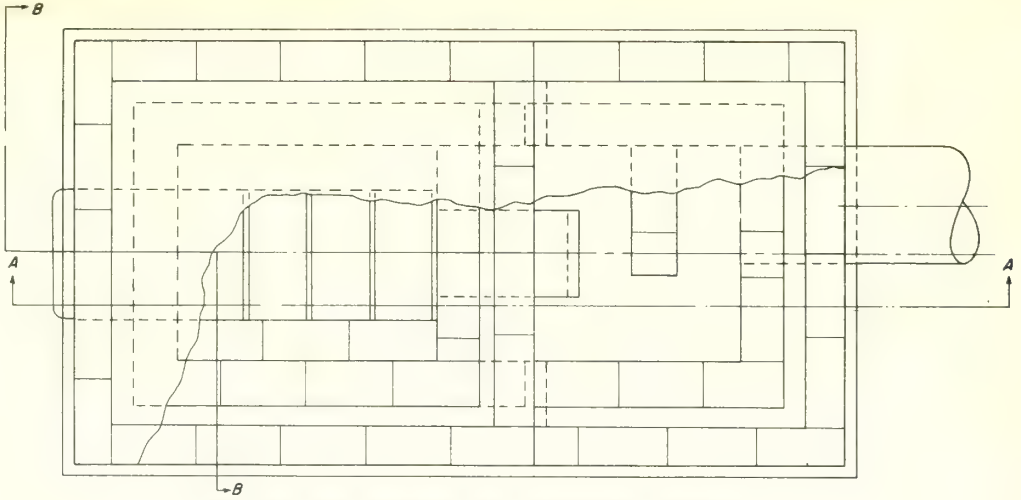
5/ Estimates are that this cost can be reduced approximately $100 by off season work and quantity production of parts.

Conclusions

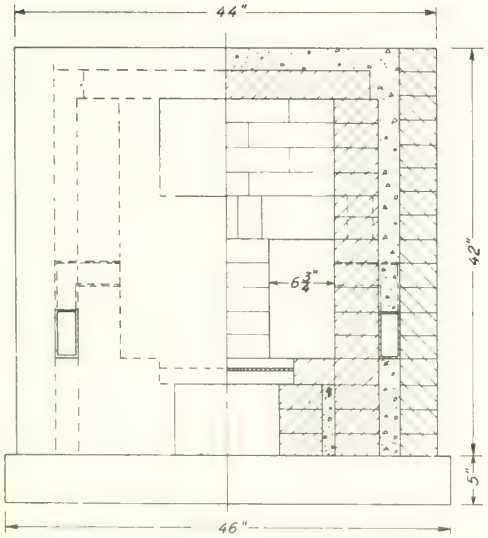
The dual type automatic wood-burning furnace has been experimentally tested and has given satisfactory service in curing tobacco with a fuel savings of as much as 100 percent over other type wood furnaces. Its initial cost is high, around $400 to $500. Fuel costs for 6 cures is low, however, near $60. This compares with a cost of $150 for oil. It has the further advantage of encouraging farmers to utilize cull wood that would otherwise have little value. Additional field tests by farmers are needed before the furnace can be generally recommended. Further information can be obtained from the Tobacco Experiment Station, Oxford, N. C., or the Southeastern Forest Experiment Station, Asheville, N. C.

APPENDIX A

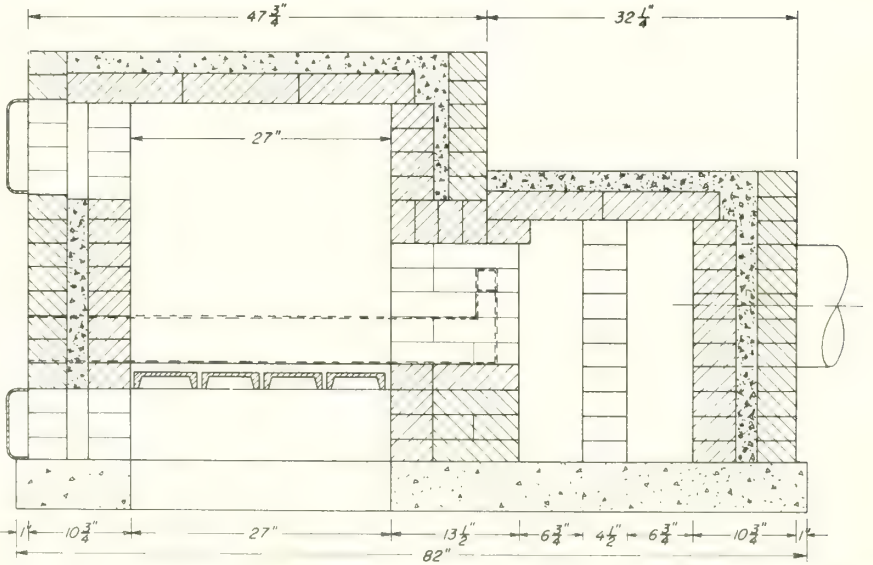
Furnace Construction, Course by Course



VIEW WITH TOP INSULATION AND SLABS PARTLY REMOVED



HALF SECTION THROUGH B-B

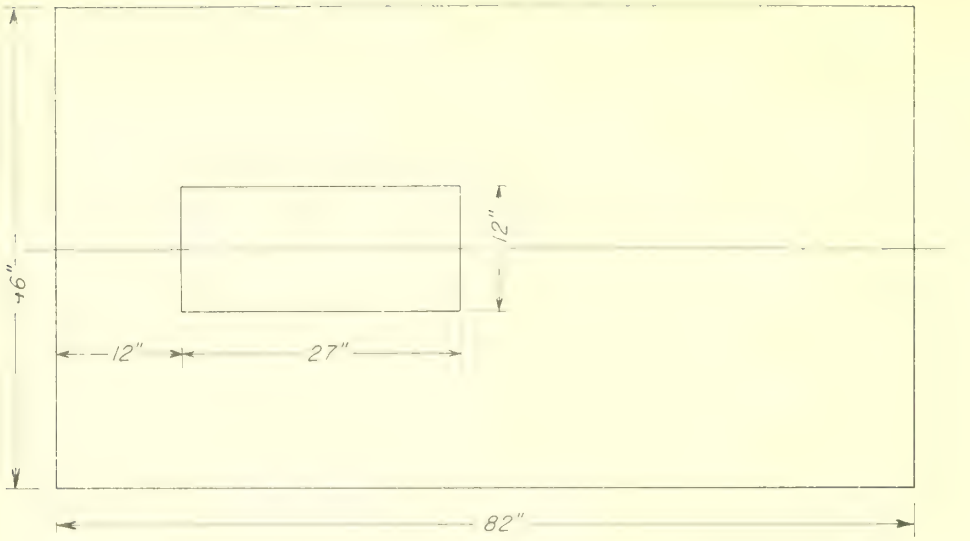


SECTION THROUGH A-A

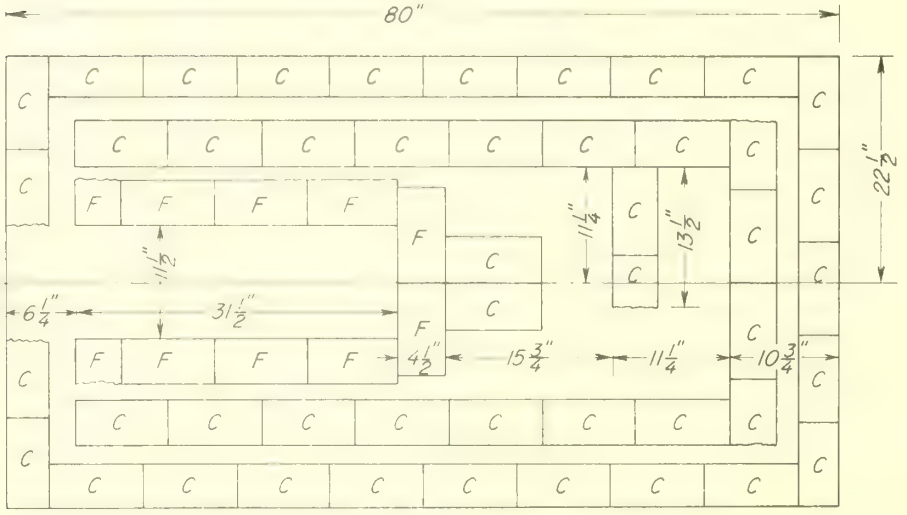
WOOD BURNING FURNACE
FOR FLUE-CURING TOBACCO

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
MADISON, WISCONSIN

Z M 86271 F



CONCRETE SLAB BASE



COURSES 1 & 3 - PUT ASH-PIT DOOR FRAME IN PLACE, PLACE LINTEL IN COURSE 3.

2

WOOD BURNING FURNACE FOR FLUE-CURING TOBACCO
U. S. DEPARTMENT OF AGRICULTURE FOREST SERVICE FOREST PRODUCTS LABORATORY MADISON, WISCONSIN

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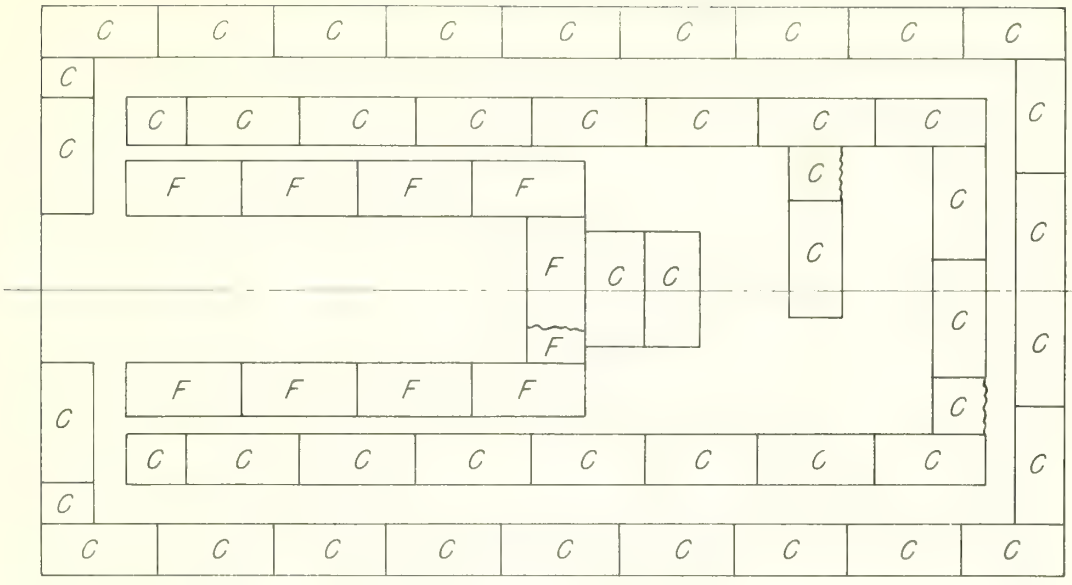
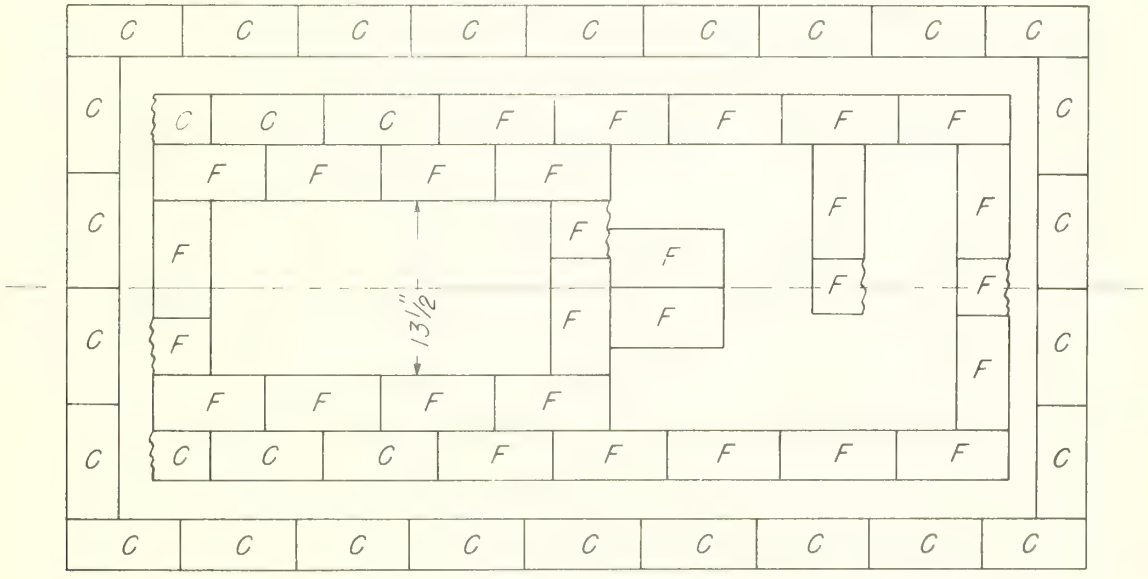


COURSE 2



COURSE 4 - PUT GRATES IN PLACE, CONTINUE FIREBRICK WALL TO COURSE 8 INCLUSIVE.

③

WOOD BURNING FURNACE
FOR FLUE-CURING TOBACCO

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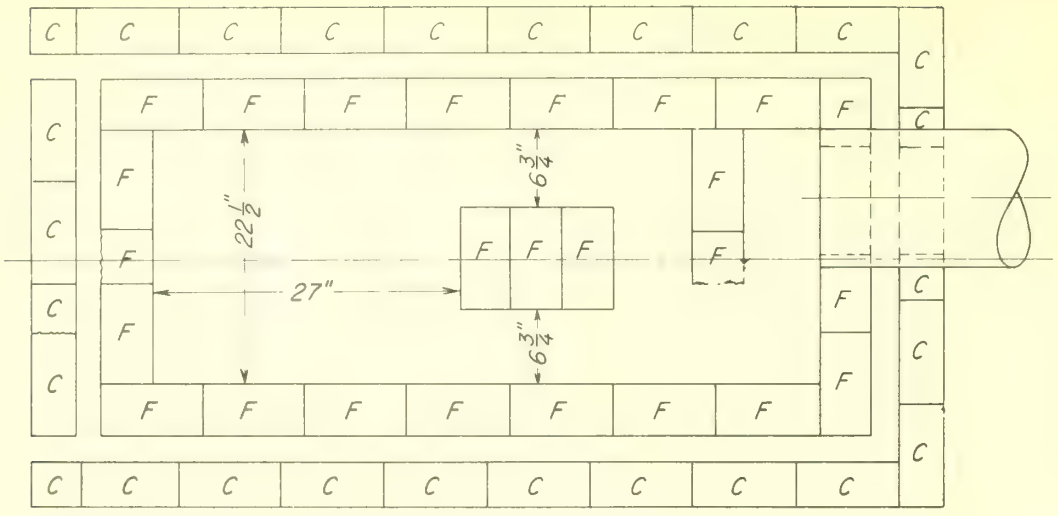
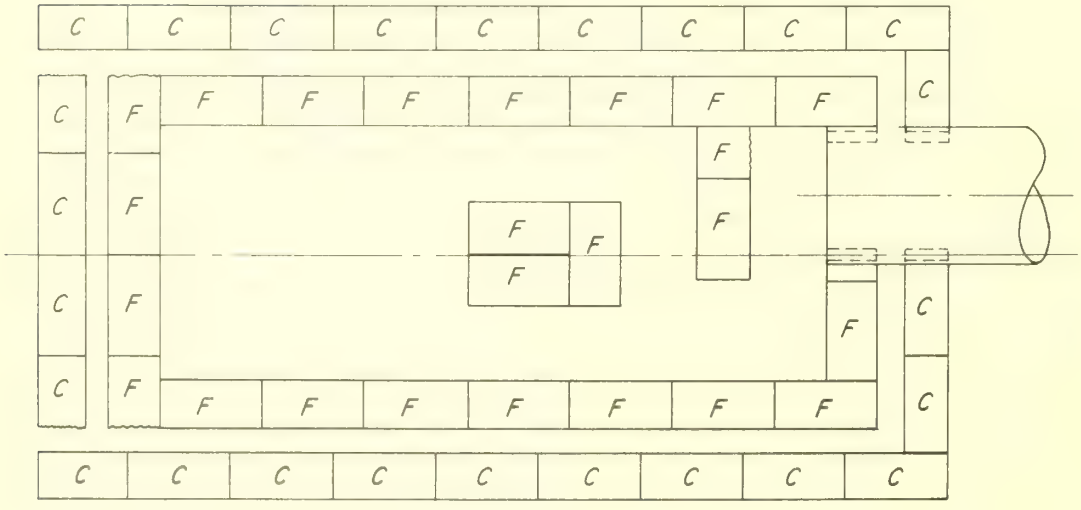


COURSE 5 - PUT THIMBLE IN PLACE, BLOCK OFF ASH-PIT OPENING WITH BOARDS SO THAT SPACE BETWEEN OUTER AND INNER WALL CAN BE FILLED WITH INSULATING CONCRETE TO TOP OF COURSE 4. PUT METAL AIR DUCT IN PLACE.

COURSES 7 & 9 - SAME AS 5 BUT BRIDGE OVER DUCT OPENING.



COURSE 6

④

WOOD BURNING FURNACE FOR FLUE-CURING TOBACCO
U. S. DEPARTMENT OF AGRICULTURE FOREST SERVICE FOREST PRODUCTS LABORATORY MADISON, WISCONSIN

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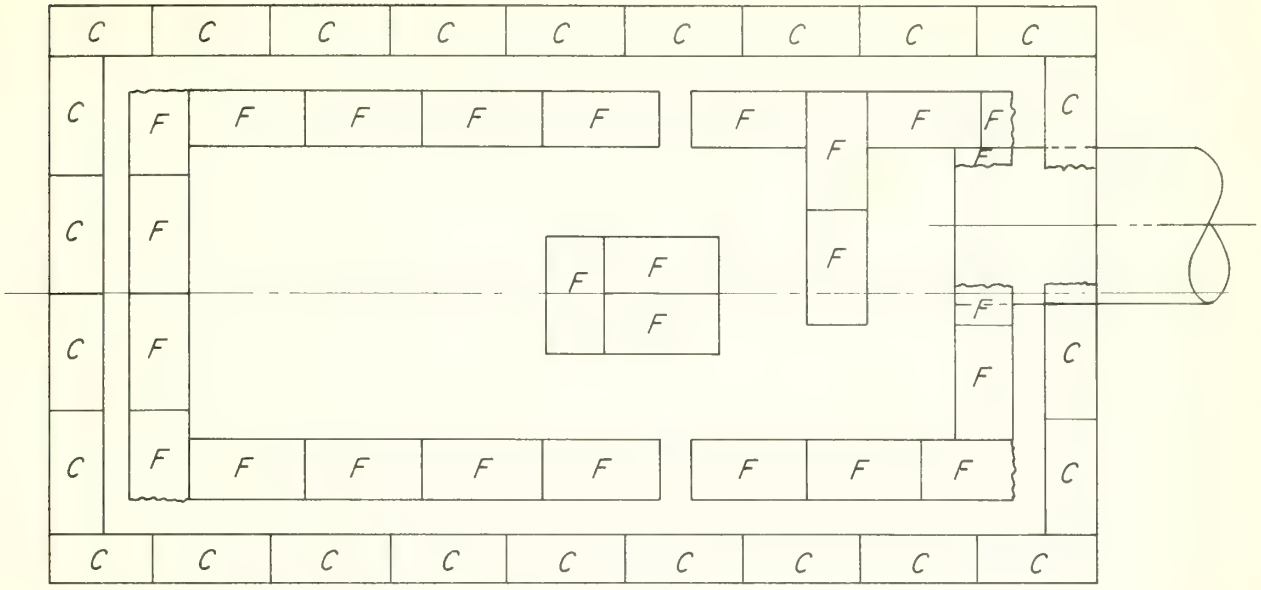
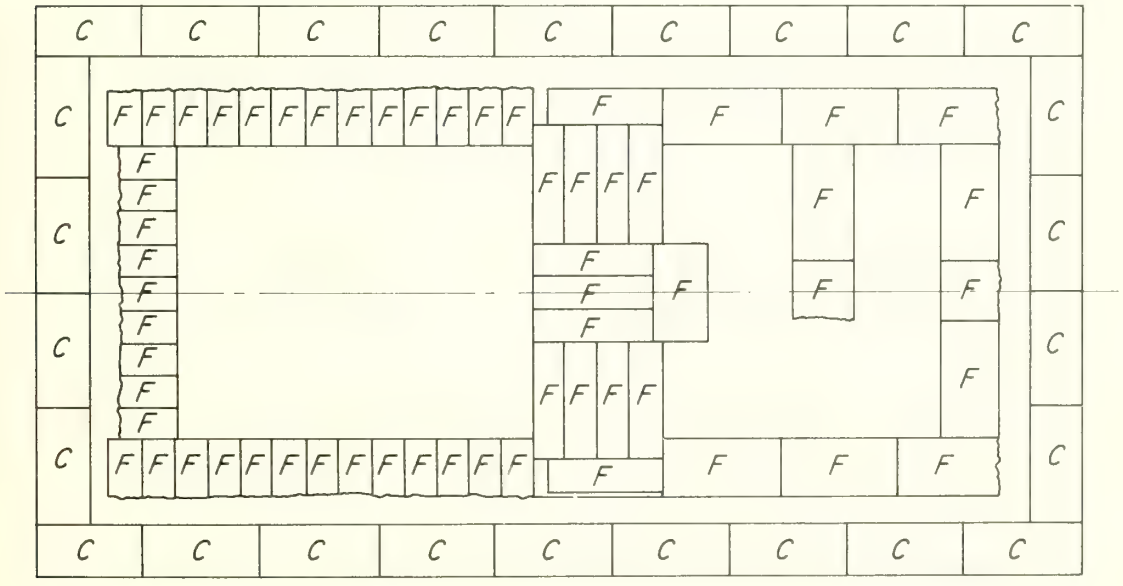


COURSE 8



COURSE 10 - FIREBRICK IN HOPPER AND ARCH ON EDGE

⑤

WOOD BURNING FURNACE
FOR FLUE-CURING TOBACCO

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
MADISON, WISCONSIN

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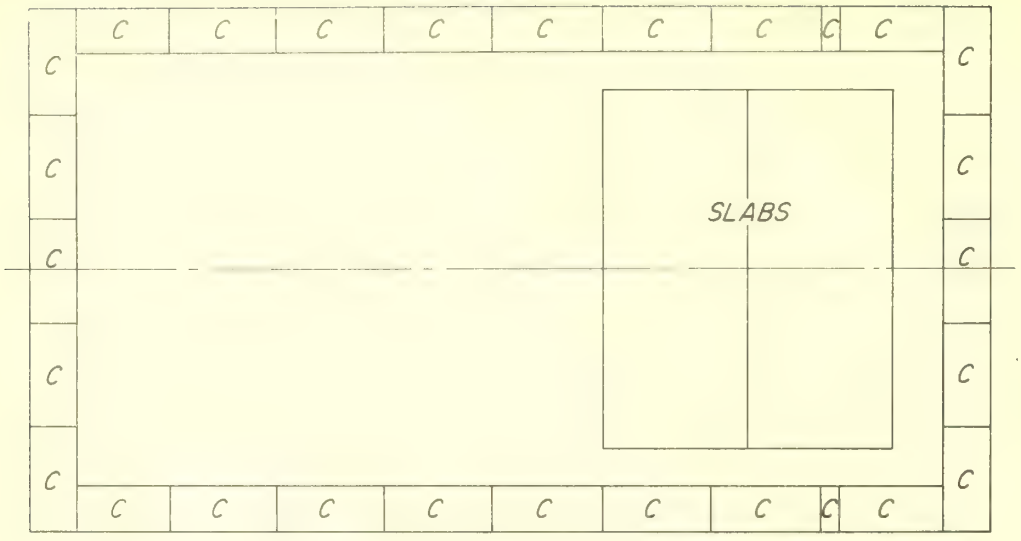
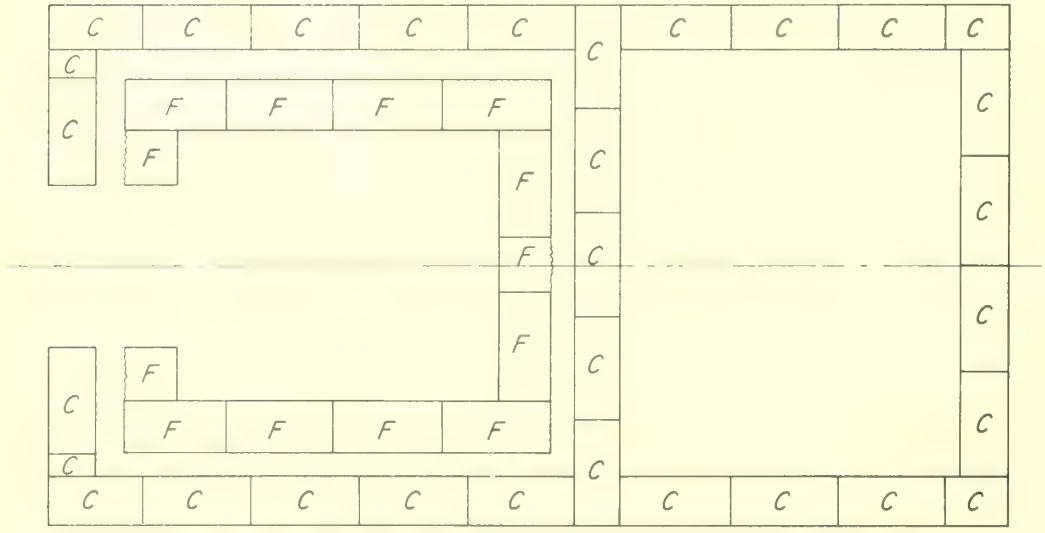


COURSE 11 - PUT SLABS IN PLACE, THEN LAY OUTER WALL SO OUTER WALL IS ABOUT LEVEL WITH INNER WALL.



COURSE 12 - PUT DOOR FRAME IN PLACE

WOOD BURNING FURNACE FOR FLUE-CURING TOBACCO
U. S. DEPARTMENT OF AGRICULTURE FOREST SERVICE FOREST PRODUCTS LABORATORY MADISON, WISCONSIN

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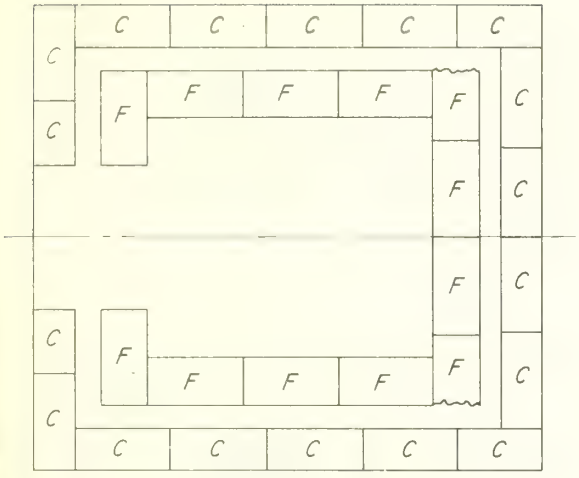
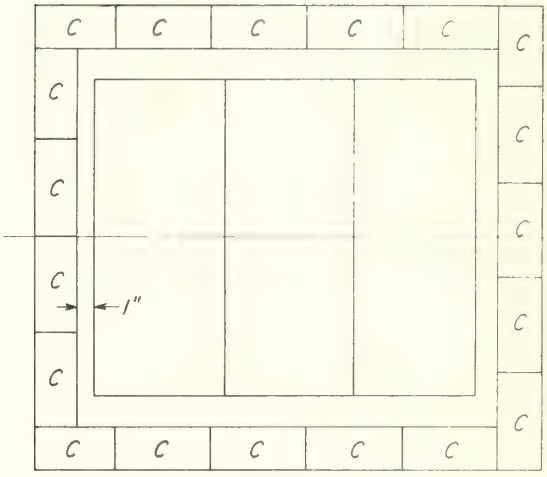
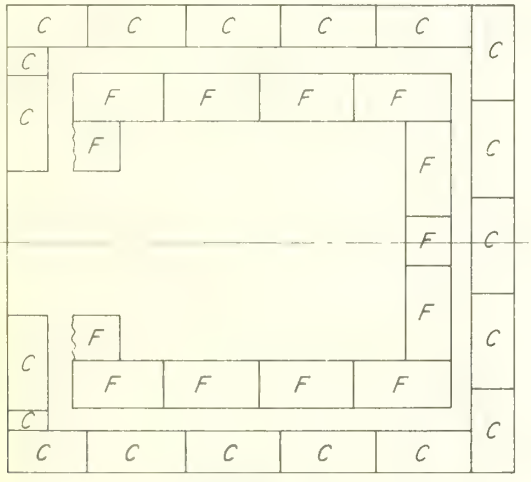


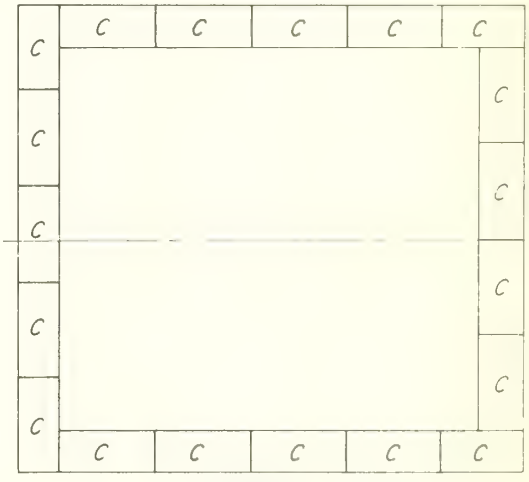
COURSES 13 & 15



COURSE 16



COURSE 14



CCURSE 17

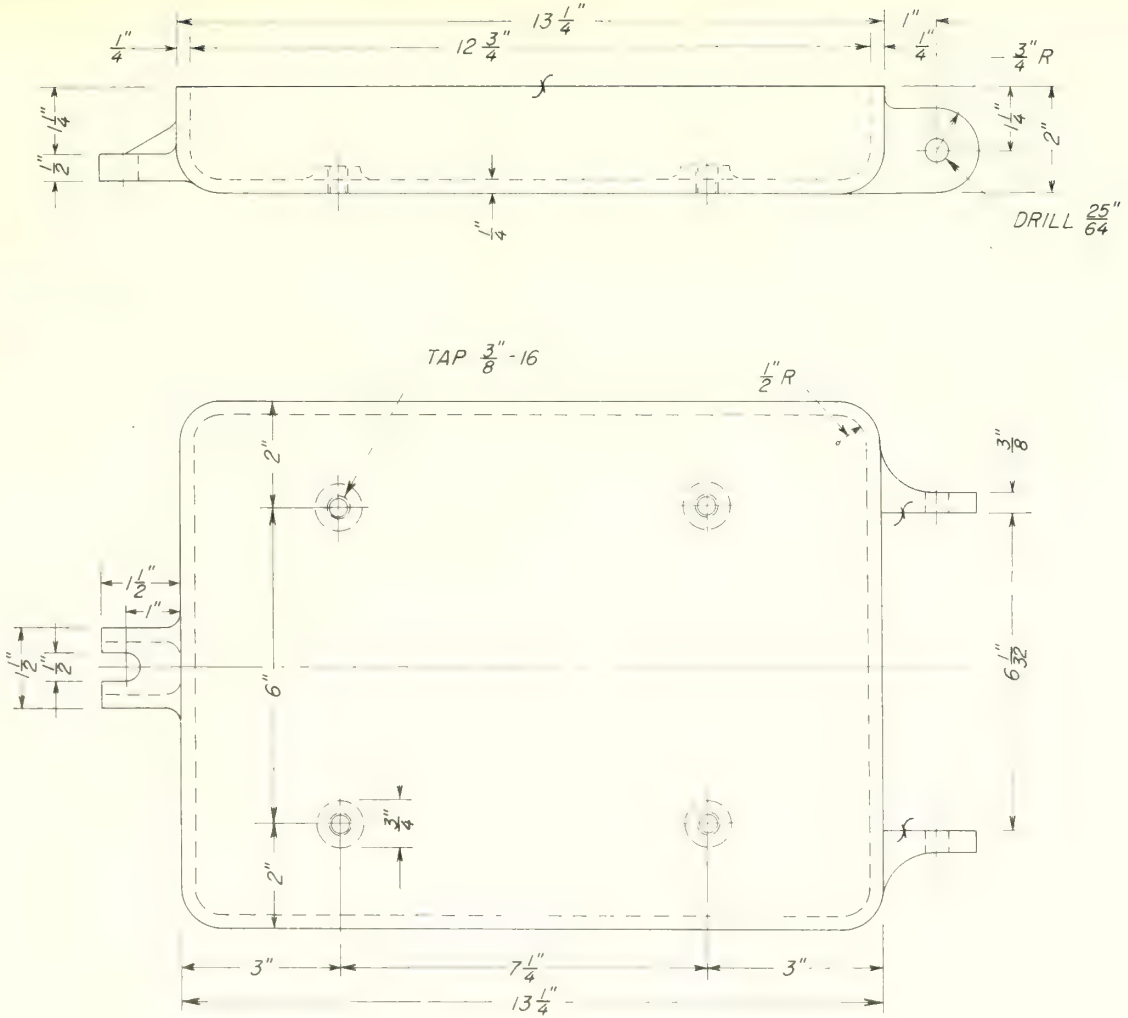
WOOD BURNING FURNACE
FOR FLUE-CURING TOBACCO

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
MADISON, WISCONSIN

Z M 86276 F

APPENDIX B

Cast Iron Parts and Metal Work

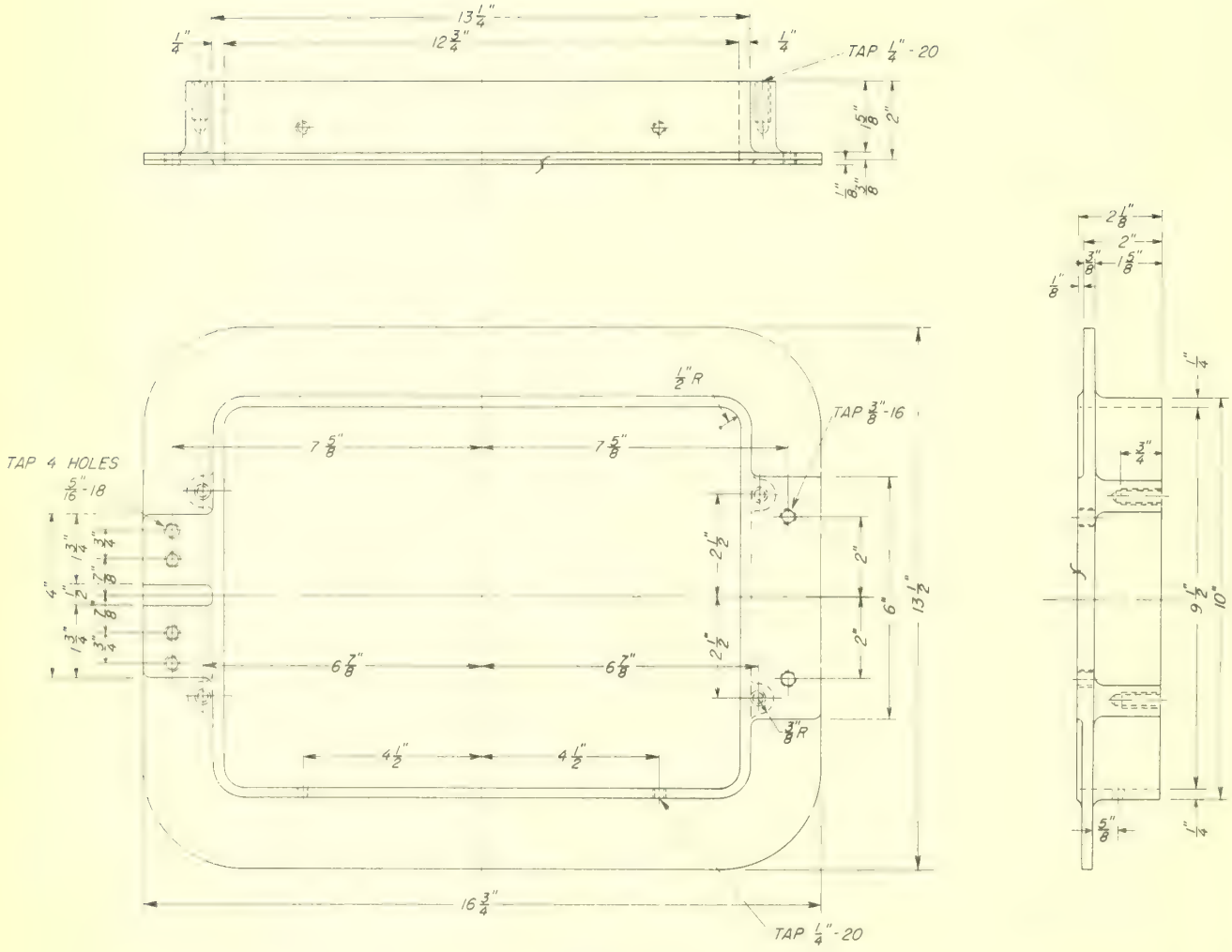


FUEL DOOR

2 REQ'D - C.I.

WOOD BURNING FURNACE FOR FLUE-CURING TOBACCO
U. S. DEPARTMENT OF AGRICULTURE FOREST SERVICE FOREST PRODUCTS LABORATORY MADISON, WISCONSIN

Z M 86277 F

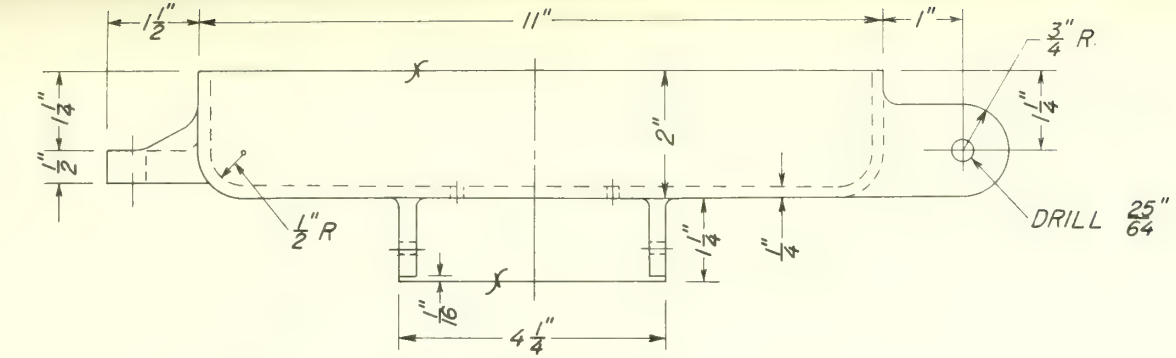


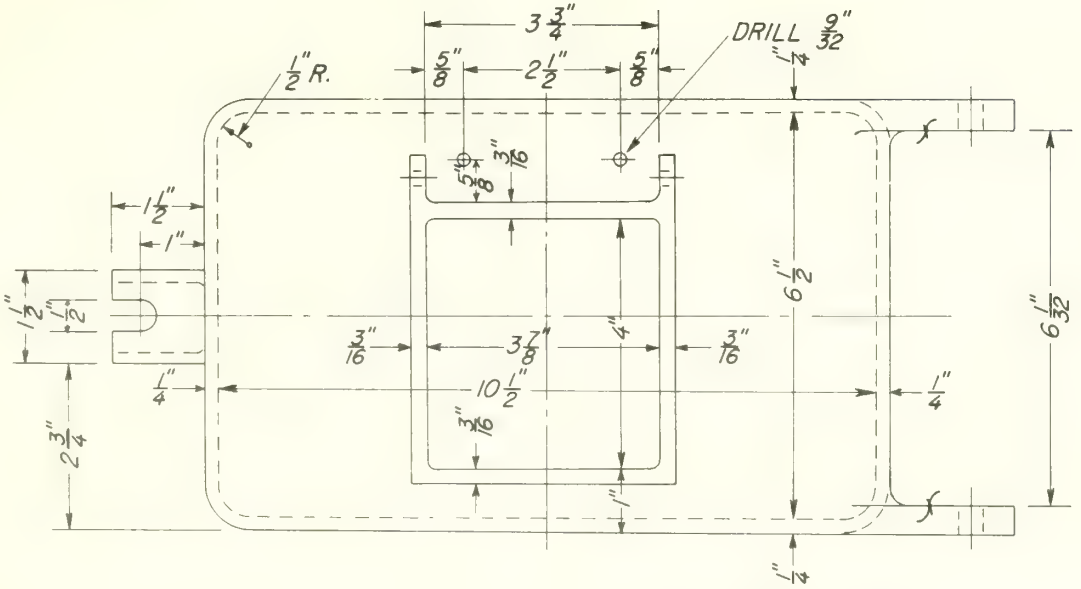
FUEL DOOR FRAME

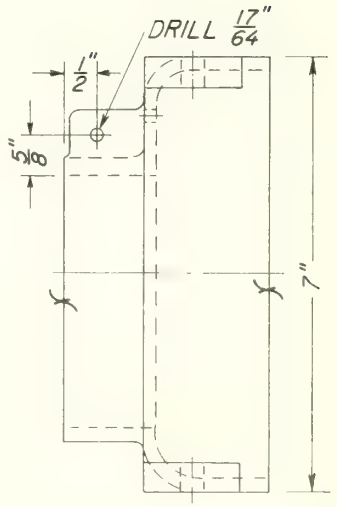
2 REQ'D - C. I.

WOOD BURNING FURNACE FOR FLUE-CURING TOBACCO
U. S. DEPARTMENT OF AGRICULTURE FOREST SERVICE FOREST PRODUCTS LABORATORY MADISON, WISCONSIN

Z M 86278 F







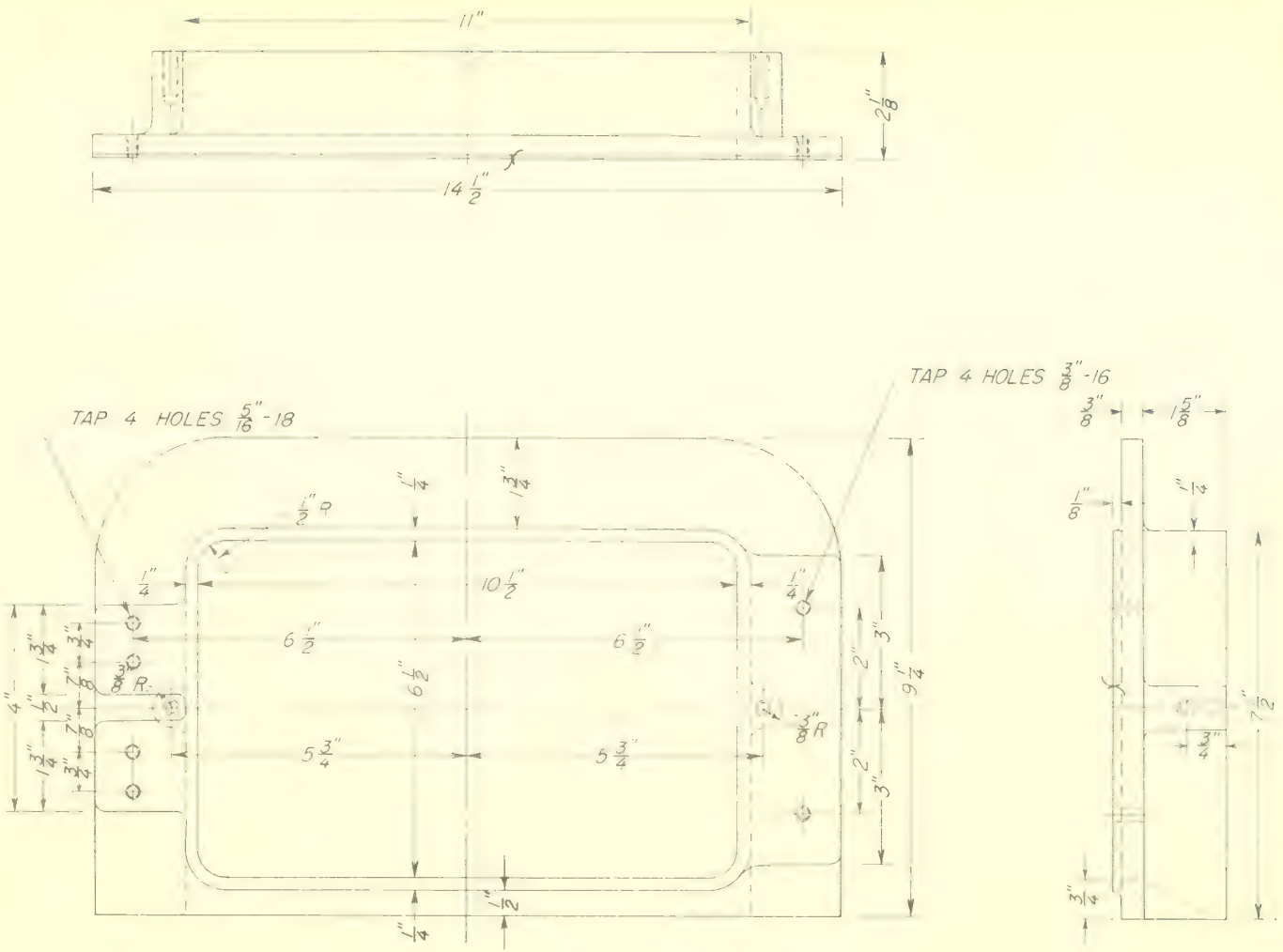
ASH—PIT DOOR

2 REQ'D - C.I.

WOOD BURNING FURNACE FOR FLUE-CURING TOBACCO
U. S. DEPARTMENT OF AGRICULTURE FOREST SERVICE FOREST PRODUCTS LABORATORY MADISON, WISCONSIN

(10)

Z M 86279 F



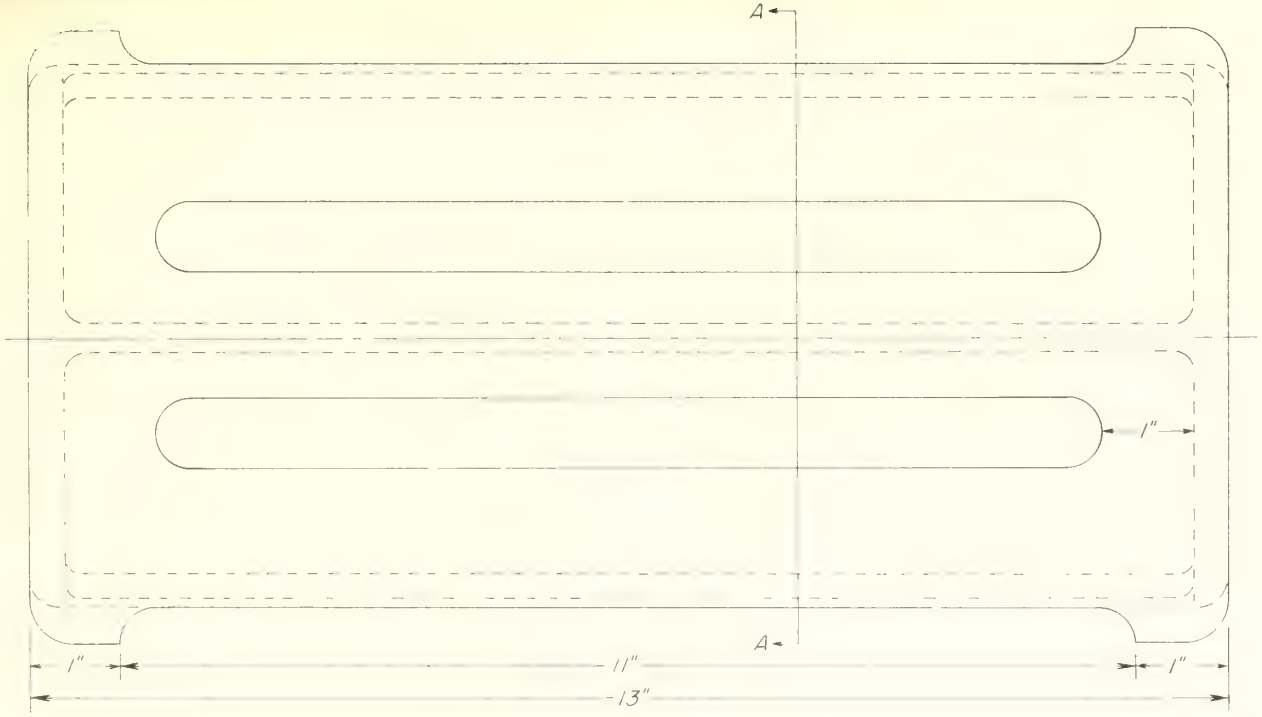
ASH-PIT DOOR FRAME

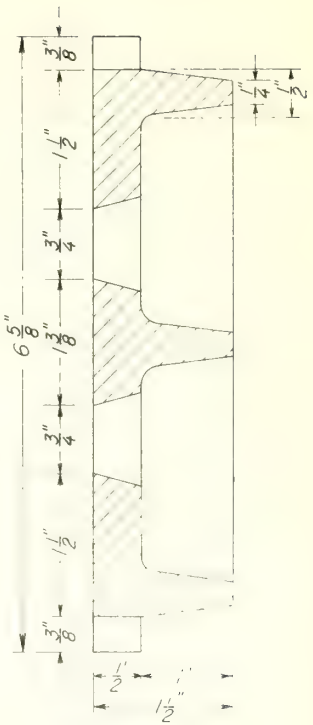
2 REQ'D - C. I.

WOOD BURNING FURNACE FOR FLUE-CURING TOBACCO
U. S. DEPARTMENT OF AGRICULTURE FOREST SERVICE FOREST PRODUCTS LABORATORY MADISON, WISCONSIN

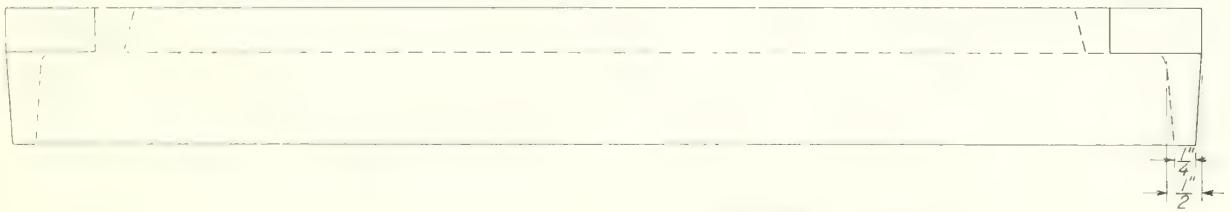
(11)

Z M 86280 F





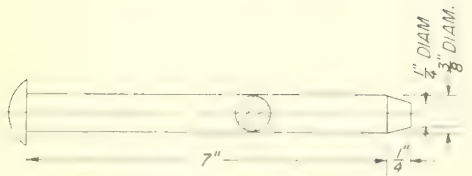
SECTION A-A



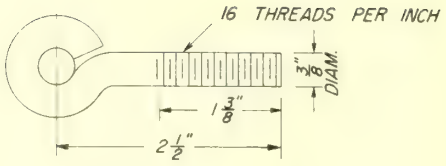
GRATE BARS

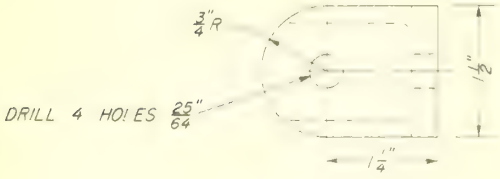
8 REQ'D - C.I.

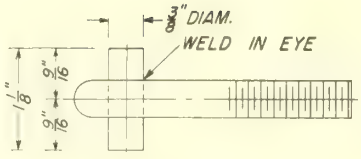
WOOD BURNING FURNACE FOR FLUE-CURING TOBACCO
U. S. DEPARTMENT OF AGRICULTURE FOREST SERVICE FOREST PRODUCTS LABORATORY MADISON, WISCONSIN



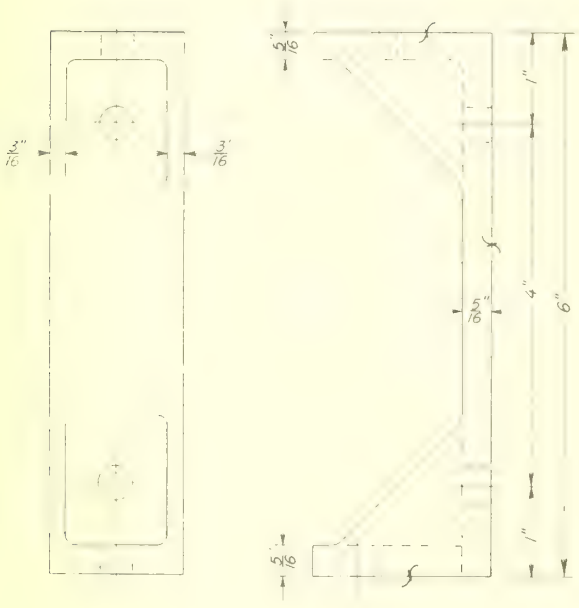
HINGE PIN
4 REQ'D



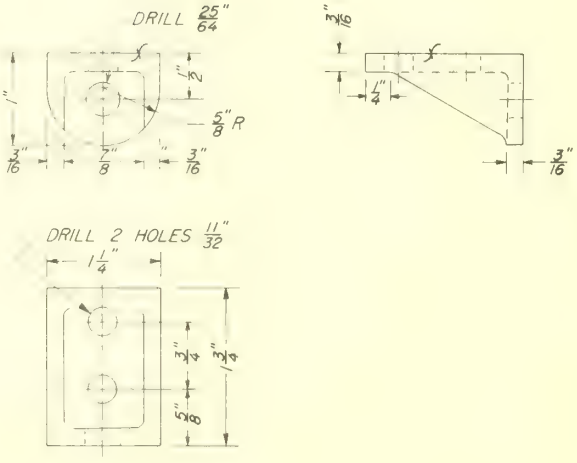




EYEBOLTS
4 REQ'D



DOOR BRACKET
4 REQ'D - C.I.

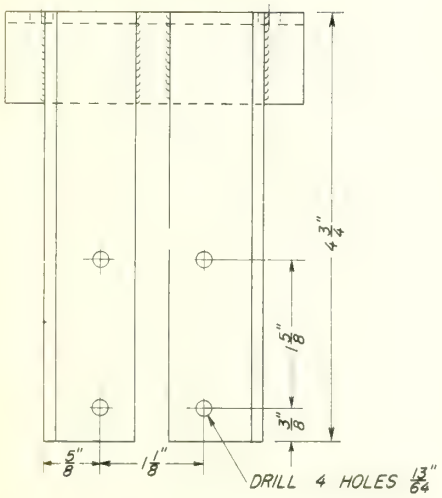


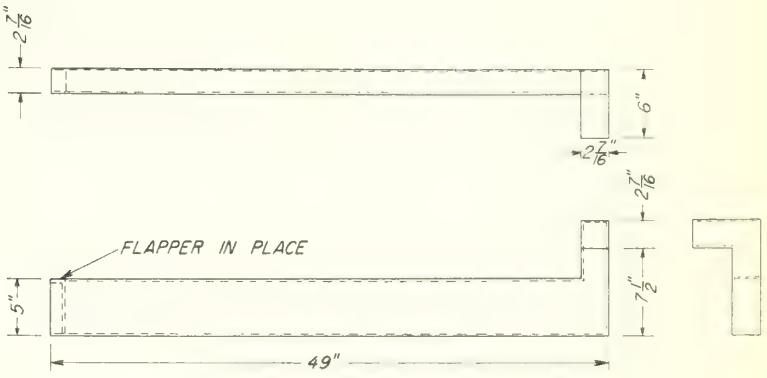
HASP BRACKET
8 REQ'D - C.I

(13)

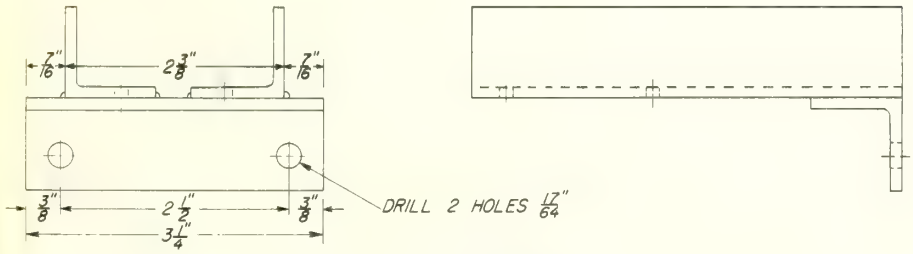
WOOD BURNING FURNACE FOR FLUE-CURING TOBACCO
U. S. DEPARTMENT OF AGRICULTURE FOREST SERVICE FOREST PRODUCTS LABORATORY MADISON, WISCONSIN

Z M 86282 F





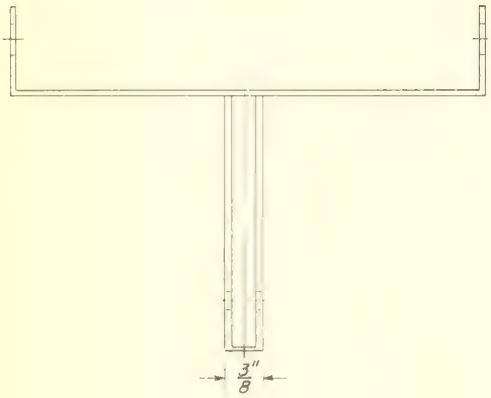
SECONDARY AIR INLETS
2 RIGHTS AND 2 LEFTS - 22 GA. IRON

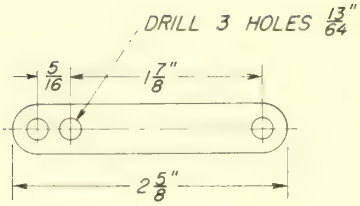


BRACKET FOR SOLENOID
2 REQ'D - 1/8" x 1" x 1" ANGLES

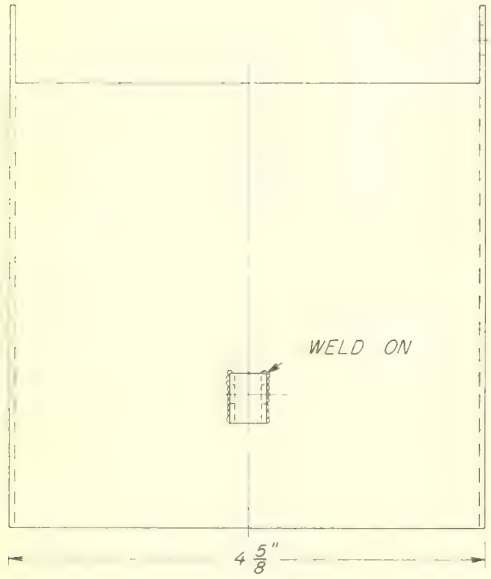
Z M 86283 F

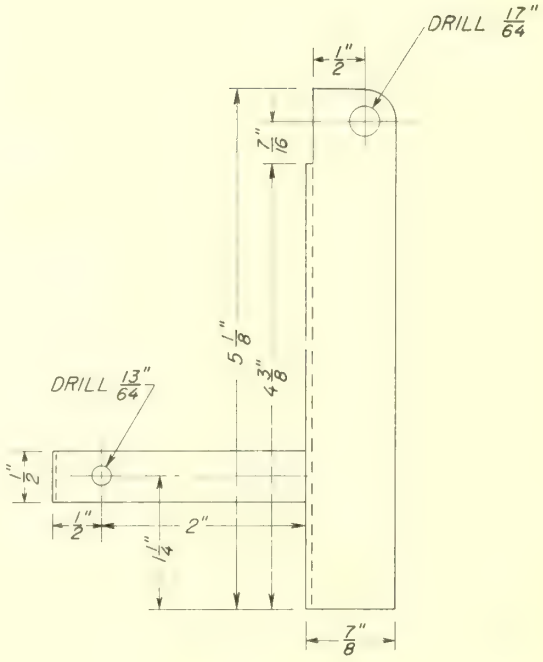
WOOD BURNING FURNACE
FOR FLUE-CURING TOBACCO
U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
MADISON, WISCONSIN





LINKAGE
1/8" x 7/16" STEEL - 2 REQ'D
4 RD. HEAD SCREWS 3/16" x 3/4" AND 8 BRASS NUTS

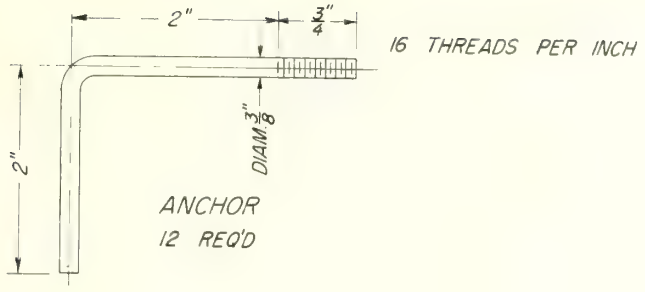




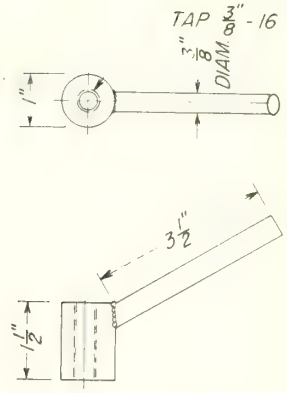
DRAFT DOOR
16 GAGE STEEL - 2 REQ'D
2 - 1/4" DIA. x 5" LONG MACHINE BOLTS

WOOD BURNING FURNACE FOR FLUE-CURING TOBACCO
U. S. DEPARTMENT OF AGRICULTURE FOREST SERVICE FOREST PRODUCTS LABORATORY MADISON, WISCONSIN

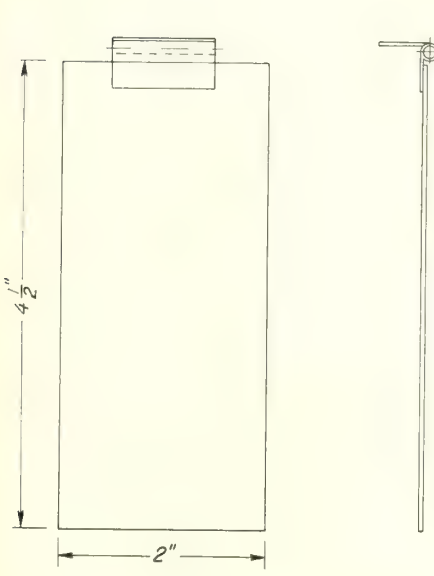
Z M 86284 F



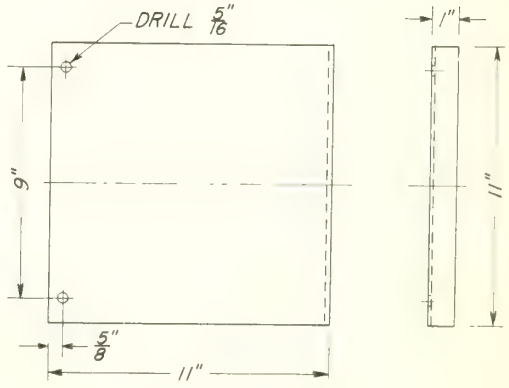
ANCHOR
12 REQ'D



WING NUTS
4 REQ'D



SECONDARY AIR FLAPPER
4 REQ'D - 26 GA. G.I.



FUEL SLIDE
2 REQ'D - 16 GA. STEEL
4 RD. HEAD 1/4" x 5/16" - 20 SCREWS

WOOD BURNING FURNACE FOR FLUE-CURING TOBACCO
U. S. DEPARTMENT OF AGRICULTURE FOREST SERVICE FOREST PRODUCTS LABORATORY MADISON, WISCONSIN

Z M 86285 F

APPENDIX C

Some Suggestions about Wood for the Furnace

Moisture content of wood has a great effect upon its efficiency as fuel. If you use green wood, you need 10 percent more fuel per cure. Therefore, it is to the farmer's advantage to cut his wood in the winter or spring before the curing season and to crib it hogpen fashion for proper seasoning. It is advisable to cut the wood in long lengths in the forest and drag or haul it to a central place where it can be cut to short lengths with a buzz saw and split if stems are more than 8 inches in diameter. For gum and other woods hard to split, a powder wedge will save much labor.

Generally speaking, hardwoods contain more heat per cord than softwoods or pines; many of the hardwoods have little value for other uses. The farmer should use low-grade scrub oak, sweet gum, hickory, and similar trees that have little value as saw timber or pulpwood; they make excellent fuel for curing tobacco. Following are some of the species of wood in the tobacco belt listed in the order of their heat value: hickory, oak, beech, birch, hard maple, locust, pine, sweet gum, sycamore, soft maple, and poplar.

In firing an open-type wood furnace the farmer often wants slightly green wood because it burns slower. Although this may be true in an open furnace, it does not hold true in an efficient furnace where the rate of burning is controlled by the amount of air permitted to get to the fire. In the type of furnace described in this report, the drier the wood the better.

CAUTION:

THE DOORS OF THE FURNACE SHOULD NOT BE OPENED EXCEPT WHEN REFUELING BECAUSE:

1. ENTERING AIR CONTAINING OXYGEN WILL IGNITE THE WOOD GASES AND EXPLODE FLAME OUT THE FUEL DOOR. SEE INSTRUCTIONS FOR REFUELING.

2. THE UNCONTROLLED ADDITION OF AIR THROUGH THE FUEL DOOR WILL RAISE THE BARN TEMPERATURE HIGHER THAN THE THERMOSTAT SETTING.

Cut this out and place it on the wall next to the furnace.

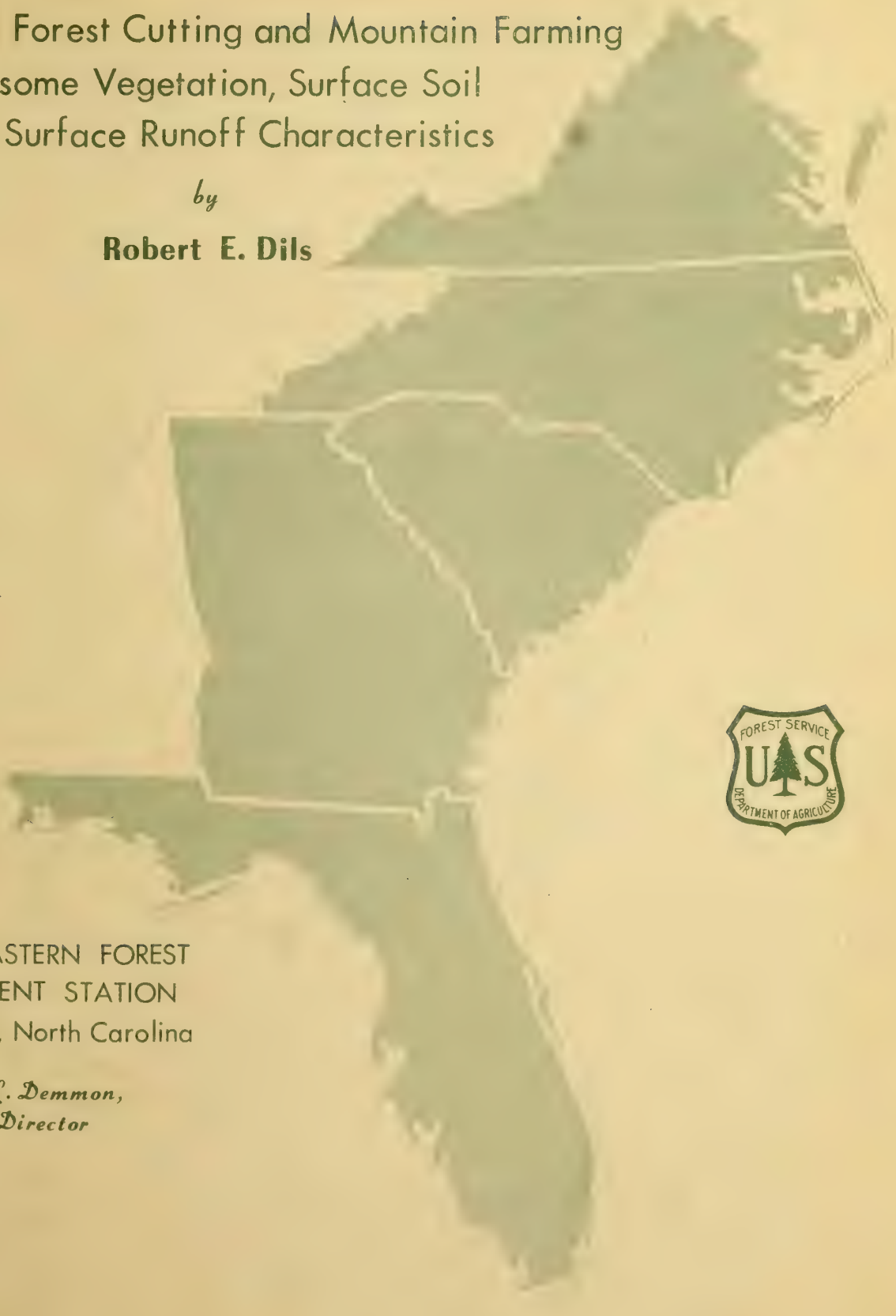
A13.63/1:24

STATION PAPER NO. 24 JUNE 1953

Influence of Forest Cutting and Mountain Farming on some Vegetation, Surface Soil and Surface Runoff Characteristics

by

Robert E. Dils



SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. Department of Agriculture - Forest Service

Acknowledgement

All of the hydrologic data used here were collected at or taken from the records of the Coweeta Hydrologic Laboratory near Franklin, North Carolina, with which the writer was associated during the summers of 1951 and 1952.

The writer wishes to express appreciation to Dr. Charles R. Hursh, Chief of the Division of Forest Influences, Southeastern Forest Experiment Station, and Edward A. Johnson, Technician-in-Charge, Coweeta Hydrologic Laboratory, for their assistance in outlining the study and their continued interest and constructive criticism.

Acknowledgement is made to Dr. Lloyd M. Turk, Dr. Eugene P. Whiteside and Dr. A. Earl Erickson of the Soil Science Department, Michigan State College, for helpful suggestions and constructive criticism, particularly in the soil analyses.

Appreciation is expressed also to Dr. H. G. Wilm, Chief, Division of Forest Influences, Forest Service, Washington, D. C., for his long-continued encouragement and inspiration.

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INFLUENCE OF FOREST CUTTING AND MOUNTAIN FARMING ON SOME VEGETATION, SURFACE SOIL AND SURFACE RUNOFF CHARACTERISTICS[1/]

by

Robert E. Dils[2/]

PURPOSE AND SCOPE

With the increasing demands made on our water supplies within the past few decades has come the realization that fundamental research concerning this basic natural resource is woefully lacking. Because the water resource is so closely linked with climate, it was the consensus of opinion for many centuries that man could alter it no more than he could the weather. This is not entirely true, for, in addition to climate, the available water supplies may be affected by the vegetation and soil factors. Through his use of the land, man exerts a very significant influence on both the vegetation and the soil. As a result, he also modifies the water resource, but the nature and extent of this modification has been a subject of much speculation and controversy.

Because of the lack of hydrologic data, it has been impossible in the past to establish a scientific basis for the management of water as a natural resource. Currently, an increasing demand for such information is being made by many public and private interests. Industry requires a dependable supply of clean water. Municipalities demand an adequate, pure water supply. Many public and civic agencies require information for flood control programs and power projects. The recreation and tourist trades lean heavily upon the nation's water resource. Fish and wildlife interests are dependent upon clear, cool streams for the production of fish and game.

1/ This paper is a portion of a dissertation submitted to the Graduate School in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Soil Science at Michigan State College, East Lansing, Michigan.

2/ Assistant Professor of Forestry, Michigan State College.

In recent years, many ambitious projects have been inaugurated; new factories have been built, cities have doubled their facilities for supplying water to an increasing population, sports and recreation areas have been developed--all at tremendous expense and all making tremendous demands on the local water resources. If the water supply is found to be adequate, clean and pure, such ventures prosper. Unfortunately, many of these efforts have been hampered by muddy streams and unexpected stream behavior. When these occur, the land-use pattern of the watershed in question is immediately examined in order to locate the source of the difficulty. Frequently, the watershed will not be entirely in natural forest, but will show a mixed pattern of usage. Small areas may be farmed, grazed or logged. This immediately occasions much heated controversy as to just which area is the cause of the trouble. When mountain farming is one of the factors which appears in a mixed land-use pattern, the decreased value of the development often has been attributed primarily to this practice. Just how harmful the cultivation of small patches of steep land may be has been the subject of much speculation.

Thousands of acres of steep forest land have been cleared for use as cropland or pasture in the Southern Appalachians. To farm such land successfully requires great skill and care. Many authorities claim that much of it should never be farmed at all. It is common knowledge that individual farmers may "wear out" many such mountain farms in a lifetime.

It is the intent of this study to determine the effects of clearing and cultivating steep forested slopes on certain surface runoff characteristics as well as to study some of the resultant biologic and edaphic changes in the watershed.

Numerous studies have been made on cultivated and forested watersheds and indirect comparisons made therefrom. To the writer's knowledge, however, there has been no report in which a forested watershed has been calibrated, clear cut and cultivated and a direct comparison made.

In this study, carried out on the Little Hurricane Watershed on the Coweeta Hydrologic Laboratory in Macon County, North Carolina, the forested watershed was calibrated from 1934 to 1940. In 1940 the area was clear cut and from 1941 to date has been subjected to mountain farming typical of the Southern Appalachian region. As nearly as possible the land has been treated as though a mountain family lived near the stream and tended the area to make its livelihood.

If the effects of clearing steep forest land on the hydrologic behavior of a small watershed can be adequately determined, it should serve as a guide to the land-use questions on larger drainages and basins.

PAST WORK

Numerous investigations have been undertaken in many localities throughout the country for the purpose of measuring runoff and erosion. Many of these studies, however, have been confined to cultivated areas and others have been made on a small-plot or lysimeter scale. The literature

has become so voluminous that no attempt is made here to review it all. Instead, only selected representative projects which provide a particularly pertinent background to the present study will be cited.

Since 1930 the Soil Conservation Service, United States Department of Agriculture, has established 19 soil conservation experiment stations including numerous cooperative projects with state agricultural experiment stations. Similarly, the Forest Service, United States Department of Agriculture, maintains 14 stations where research in watershed management is currently being conducted. In addition, at least nine other watershed research centers are conducting studies under the jurisdiction of other federal and state agencies including the Corps of Engineers in the Department of the Army, the Weather Bureau in the Department of Commerce, the Geological Survey in the Department of the Interior, the Tennessee Valley Authority, and the New York and Michigan State Departments of Conservation.

Stations at Statesville, North Carolina (4), and Watkinsville, Georgia (27), both on the Piedmont, are engaged in cropping and erosion control measures, and measure runoff from small plots, lysimeters, and field watersheds. A comparison of land use practices at the former station indicates decreasing soil losses in the following order: fallow, continuous cotton, rotation (cotton and corn with winter cover crops), grass, woods burned annually, and unburned woods.

In surface runoff the trends are the same except that the burned woods area yields a higher percent of precipitation appearing as surface runoff than does the grass area. In the case of the fallow area, over 17-1/2 percent of the precipitation appears as surface runoff, as compared with 0.7 percent for the unburned woods.

The first experimental watershed project of the Soil Conservation Service was established near Coshocton, Ohio, in the Muskingum Watershed Conservancy District (20, 27). Intensive studies are being made there on the effects of land use and erosion-control practices on the conservation of soil and moisture and on flood flows for 44 complete watersheds supporting various cover types. These watersheds range in size from three to 4,600 acres. An analysis of soil-water relationships on four small watersheds at Coshocton was made by Dreibelbis and Post (10) in 1941. A comparison among a wooded, pastured and two cultivated watersheds all on similar soils showed a much lower volume of surface runoff for the wooded area. On the wooded watershed only 0.11 inch or 0.2 percent of the precipitation ran off compared with 0.60 inch and 1.4 percent for the pastured area and 6.35 inches or 15.0 percent runoff for one of the cultivated areas.

A 250-acre experimental tract near Zanesville, Ohio, including three gaged watersheds, was established in 1933 to study the effect of land use on runoff and erosion. Included in this study is a 2.23-acre wooded watershed. For the 5-year period from 1934-1938, Borst and Woodburn (7) noted the average soil loss from this watershed as 0.017 tons per acre per year. The average annual runoff was noted as 0.1246 inches, which amounts to approximately 0.34 percent of the average annual precipitation.

Near LaCrosse, Wisconsin (14) a 160-acre tract contains three gaged watersheds: a pasture cleared of timber, a grazed hardwood forest and a

typical ungrazed woodlot. An analysis of eight intense storms occurring in 1935 indicated that about 8-1/2 and 3 percent of the precipitation appeared as surface runoff on the timbered-grazed and cleared-grazed watersheds respectively, while on the ungrazed wooded area runoff occurred only twice and then in quantities so small as to be insignificant. The same trends were indicated for soil losses from the watersheds.

An experimental watershed project for the Blacklands region has been established on the Brazos Drainage Basin near Waco, Texas (27), where erosion, land use, hydrologic and soil data are being studied on thirty watersheds. Included in these studies are several wooded plots. Analysis of soil losses and surface runoff indicate similar results to those obtained at Statesville, N. C. Plots on virgin woodlot yielded only 0.122 percent surface runoff and 0.002 tons per acre soil loss compared with nearly 30 and 10 percent surface runoff and 65 and 23 tons per acre per year soil loss for fallow and continuous cotton plots respectively.

A project designed to study the effects of land use and cultural practices on surface runoff was established in 1940 jointly by the Soil Conservation Service and the Purdue University Agricultural Experiment Station at Lafayette, Indiana (3). Included in the twenty gaged drainage areas are two wooded watersheds. Up to 1949, however, no treatment of the wooded watersheds had been attempted.

A similar study involving two small agricultural watersheds and one wooded watershed was initiated in 1940 by the Soil Conservation Service in cooperation with the Michigan State College Agricultural Experiment Station near East Lansing, Michigan (12, 22). This project is unique in that the majority of the installations on the two cultivated watersheds are designed to record the results directly on one master recorder and switch panel. The primary objective of this installation is to study the hydrology of farm lands under winter conditions of snow-cover and frozen soil. Results of the investigations to date indicate a marked difference in soil losses between the wooded watershed and the two agricultural watersheds. Total soil losses from the wooded watershed for a 10-year period amounted to only 64 pounds as compared with many tons from the two cultivated areas. Similar differences in surface runoff were noted except under conditions of frozen ground and snow cover. A commercial clear-cut treatment was applied to the wooded watershed in 1951; however, results of this treatment will not be available for at least 5 years.

Experimental watershed studies by the Forest Service, United States Department of Agriculture, are being conducted at six of the Forest Experiment Stations: Southeastern, California, Southwestern, Rocky Mountain, Intermountain, and Northeastern (27).

At the Southeastern Station, hydrologic studies are being made at the Calhoun Experimental Forest near Union, South Carolina, and at the Coweeta Hydrologic Laboratory near Franklin, North Carolina. At the Coweeta station (16, 25), in addition to the study covered herein, research projects include the determination of the effects of the following treatments upon water yield and water quality: (a) permanent complete removal of all major vegetation, (b) temporary complete removal of all major vegetation, (c) removal of riparian vegetation, (d) local logging practices, (e) woodland grazing, (f) removal of understory vegetation (laurel and rhododendron), (g) temporary defoliation by gas, and (h) forest fires.

The results of investigations being conducted at Coweeta are: (a) cutting all trees on a steep, heavily forested watershed and annually cutting back the sprouts (with no removal of wood products and no disturbance to soil) increases water yields by 17 area inches annually; (b) similar cutting, but with sprouts allowed to grow back, increases water yield approximately 17 inches and this increase becomes progressively less as the coppice stand grows older; (c) cutting streambank vegetation tends to eliminate diurnal fluctuations in stream flow; (d) local logging practices, particularly poorly located and constructed logging roads, effect a marked increase in erosion and stream turbidity; (e) woodland grazing brings about a marked increase in overland storm runoff and erosion and shows that the cattle grazed on the watershed fail to thrive (17); (f) the removal of an understory of laurel and rhododendron effects an increase in water yield of approximately 3 area inches per year; (g) preliminary observations indicate that temporary defoliation of vegetation by gas may be used as an emergency measure in extreme drought periods to reduce transpiration and thus increase water yields.

The major work center for the California Forest and Range Experiment Station is the San Dimas Experimental Forest, near Los Angeles. Projects are under way here to study the disposition of rainfall as influenced by watershed conditions, including vegetation, soils, geology and topography; and to develop methods of watershed management, including the treatment of areas denuded by fire, to assure maximum yield of usable water and satisfactory regulation of flood runoff and erosion. Installations include 17 watersheds, 18 experimental plots and 26 large lysimeters.

Forest influences and watershed management investigations at the Southwestern Forest and Range Experiment Station are carried out on the Sierra Ancha Experimental Forest near Globe, Arizona. Work projects there are designed to determine the influence of vegetation (forest, evergreen shrub, and range) on stream flow, water uses, water losses, erosion and sediment production. Gaged watersheds, plots, and natural lysimeters are utilized. In addition to the Sierra Ancha Experimental Forest, experimental plots are located in representative areas throughout the Salt River Watershed. Plot studies on range land on the Sierra Ancha station demonstrated that ungrazed range land with good plant cover produced higher water yields and much lower soil losses than overgrazed range with poor ground cover (26).

Hydrologic investigations of the Rocky Mountain Forest and Range Experiment Station are carried out at the Fraser Experimental Forest near Grand Lake, Colorado; the Manitou Experimental Forest near Colorado Springs, Colorado; and at the Western Slope Research Center near Delta, Colorado. At the Manitou station, studies are being made on the influence of grazing, timber cutting, and revegetation of depleted watershed lands upon water supplies and more particularly upon erosion and sedimentation. Experiments at the Fraser Experimental Forest are designed to show the influence of lodgepole pine and spruce-fir forests and of the cutting of this timber upon the yield of water largely from stored snow. At the Western Slope Research Center major effort is devoted to the analysis of range and watershed problems for drainage basins of western Colorado. Small grazing and reseeding projects have been established and plans are being drawn for studies of the effects of vegetation and grazing on infiltration and erosion.

At the Intermountain Forest and Range Experiment Station (2, 3) tests are under way to study the effects of forest, brush and herbaceous plant cover in natural, depleted and restored condition on the infiltration, storage, fertility, biology and stability of forest and range land soils; to determine land use practices for stabilizing eroding watershed soils and for maintaining soil stability under the impact of grazing, logging and other wildland uses. Studies are being conducted on coarse, granitic soils of southwest Idaho; various soils on steep slopes of the Wasatch Mountains in northern Utah; and on heavy limestone soils on the Wasatch Plateau in central Utah.

A surface infiltration study made on the Uinta National Forest in Utah in 1951 indicates that infiltration rates averaged from 5 to 50 percent lower on grazed sites than on ungrazed areas. Storm runoff from the grazed plots ranged from 50 to 100 percent more than on the ungrazed areas, and soil losses on the grazed plots averaged six to eight times more than on ungrazed areas (28).

At the Northeastern Forest Experiment Station, a study was initiated in November, 1948 on the Lehigh-Delaware Experimental Forest (23) of about 1800 acres to determine the influence of the present scrub-oak cover on runoff. After a period of calibration it is planned to convert the cover from scrub-oak to a better forest type by forest management and protection measures and to evaluate the effect of these changes in cover on runoff and ground water.

The earliest hydrologic investigation in this country concerned with the influence of forests on streamflow and runoff was initiated in 1909 by the United States Forest Service and the United States Weather Bureau at Wagon Wheel Gap, Colorado. Bates and Henry (5) reported in 1927 that the cutting of forest cover increased the total annual water yield, increased water yield from snow and produced increased erosion. They further indicated that the results were blurred by such conditions as porous soils, thin original cover and prolific sprouting of aspen.

One of the earliest investigations was that initiated by Ramser in 1917 near Jackson, Tennessee. He worked with six watersheds varying in size from 1.25 to 112 acres, five of which were in mixed land use and contained forest cover varying from 14 to 55 percent. Ramser reported in 1927 (19) that forest cover has a decided influence in reducing the rate of runoff from a watershed except when antecedent rainfall has been high, in which case the influence is slight.

In 1932 a study was started by the Geological Survey, United States Department of Interior, in cooperation with the State of New York Conservation Department to determine the influence of reforestation on stream flow in state forests in central New York. Submarginal lands were purchased and planted to coniferous tree species. Ayer (1) reported in 1949 that up to that time practically no significant change in runoff had been effected.

One of the most recent reports is that of the White Hollow Watershed in Union County, Tennessee published by the Tennessee Valley Authority in 1951 (24). The 1715-acre White Hollow Watershed was set aside for watershed studies in 1936. Following acquisition, watershed management included extensive erosion-control operations and tree planting. The study shows the following changes in surface runoff and other hydrologic characteristics as a result of

15 years of improvement and management: (a) The improvement in forest cover which occurred resulted in greater watershed protection without measurable decrease in water yield. (b) There was no shift in the seasonal runoff pattern as a result of land-use changes. (c) No measurable change took place in the total quantity of evapo-transpiration plus other losses. Apparently, since a greater density of vegetal cover must be supported by greater water use through transpiration, balancing factors were in operation. (d) Peak discharges during the summer season were markedly reduced. Reductions in winter peak discharge rates were not appreciable. (e) The greater part of the peak discharge reduction occurred in the first two or three years of investigations, smaller reductions continuing after that time. (f) Modification of summer peak discharges were so great that the frequency of peaks during the latter years was much less than during the earlier years. (g) The time distribution of surface runoff was materially changed. Surface runoff discharge was prolonged to produce a more sustained flow. (h) Comparison of sediment records based upon manually collected samples during early years with records obtained during the past year (1950) by means of an automatic sampler shows clearly that there has been a very material reduction in sediment load during the 15-year period of observations.

It is apparent, after a review of the literature, that a direct comparison of the results of this study with any previously reported is virtually impossible. Many studies have demonstrated that watersheds or plots with undisturbed forest cover yield less surface runoff and produces less soil loss than grazed or burned forests, pastures and croplands. In few cases, however, have attempts been made to show changes in surface runoff except in terms of total surface runoff expressed as a percent of the precipitation.

The study made in this report is unique in that the watershed was calibrated under forest conditions, the forest cover was removed and land use practices then applied. In addition, an adjacent watershed with similar characteristics was maintained in continuous forest cover, thus providing a further control. Consequently, an opportunity was provided to study more detailed changes in surface runoff.

THE COWEETA HYDROLOGIC LABORATORY

With the recognition of the need for additional research in watershed management came the realization also that the selection of sites for such research would be complicated and difficult. Foresters, hydrologists and engineers contributed rigid specifications which had to be fulfilled if the findings were to be valid and of more than local significance.

One area which met every important requirement was a 5,600-acre tract in the Nantahala Mountains of western North Carolina. This tract, established in 1933 by the United States Forest Service, is now internationally known as the Coweeta Hydrologic Laboratory. Several factors combine to make the area ideal as a natural laboratory suitable for fundamental hydrologic research. Rainfall is high, averaging 72 inches per year, and is rather uniformly distributed throughout the year. Because of the frequency of storms and the uniformity of the storm pattern, it is possible to obtain

valid results in much shorter time than in an area of less precipitation. Approximately 98 percent of the precipitation occurs as rain, so there is little snow to complicate the studies.

Topographically, this particular section is also ideal in that its steep slopes and sharp ridges form natural boundaries for the many small drainage basins--each an independent hydrologic unit--necessary for research of this type. Elevations vary from 2,200 to 5,200 feet within the boundaries of the station.

Although over half of the Coweeta area was cut over 25 years before the government acquired ownership, land use practices have altered the character of the forest itself very little. A dense mixed-hardwood forest, typical of much of eastern United States, is predominant at Coweeta. The cut-over lands support second-growth forest and the remainder of the land is in old growth. Chestnut was formerly the major species but has been wiped out by the blight. The largest part of the forest is now in oak-hickory. Another 15 percent is in cove hardwoods: yellow-poplar and northern red oak, intermixed with hemlock along the streams. Sugar maple, yellow birch, beech and pitch pine occur occasionally at the higher elevations.

Because of the similarity of this area to many other parts of the country and because of the favorable pattern of precipitation, data derived from studies on the Coweeta tract can be applied elsewhere. Consequently, research conducted here in water behavior and management has national as well as local significance.

THE LITTLE HURRICANE WATERSHED

The Little Hurricane Watershed, designated as drainage No. 3, is located in the Coweeta Hydrologic Laboratory, Macon County, North Carolina. Its location within the Coweeta area is shown in figure 1 along with the control watershed, No. 2. The waters of the Little Hurricane Branch flow into Shope Creek and thence into Coweeta Creek, which is a tributary of the Little Tennessee River. Figure 2 shows an over all view and map of the study watershed. Its aspect or exposure is essentially southeast.

Land Use History

In 1835 a hurricane is reported to have levelled all the timber in the Little Hurricane and the Hurricane drainage adjacent to it; hence the names of the watersheds. Prior to 1857 white settlers pushing into this region grazed the drainage area to some extent. As the Indians before them had done, the settlers practices semi-annual burning of the woods in order to improve the quality of the grazing. In 1857 the second-growth timber on the lower ten acres of the watershed was cleared for farming and the area was cultivated until 1887. This included nearly all of the areas which are now the lower pasture and abandoned cornfield. The yields became so low that the fields were then used only for grazing until 1900.

In 1901 the area was included in the land purchased by the Nantahala Company, a land speculation group. From 1901 until 1940 "third-growth" timber, largely of the oak-chestnut and cove hardwood types re-established

Figure 1.--Individual drainage areas at Coweeta.

itself. By 1934 the dominant trees were 18-20 inches in diameter. The chestnut, however, had dropped out because of the blight.

Only the best quality oak, chestnut and yellow-poplar was logged from the second growth forest adjoining the old field in 1914. The remaining trees were left unharmed except for the damage occasioned by the logging.

The U. S. Forest Service acquired the area in 1923 and it became a part of the Nantahala National Forest. In 1934 the drainage was included in the area set aside as the Coweeta Experimental Forest. This name was officially changed to the Coweeta Hydrologic Laboratory in 1949.

After a period of standardization or calibration starting in 1934, the watershed was clear cut in 1940 preparatory to the "mountain farming" treatment. Figure 3 shows clearing operations by CCC enrollees during the winter of that year.

Figure 2.--The Little Hurricane watershed comprises 22.79 acres.

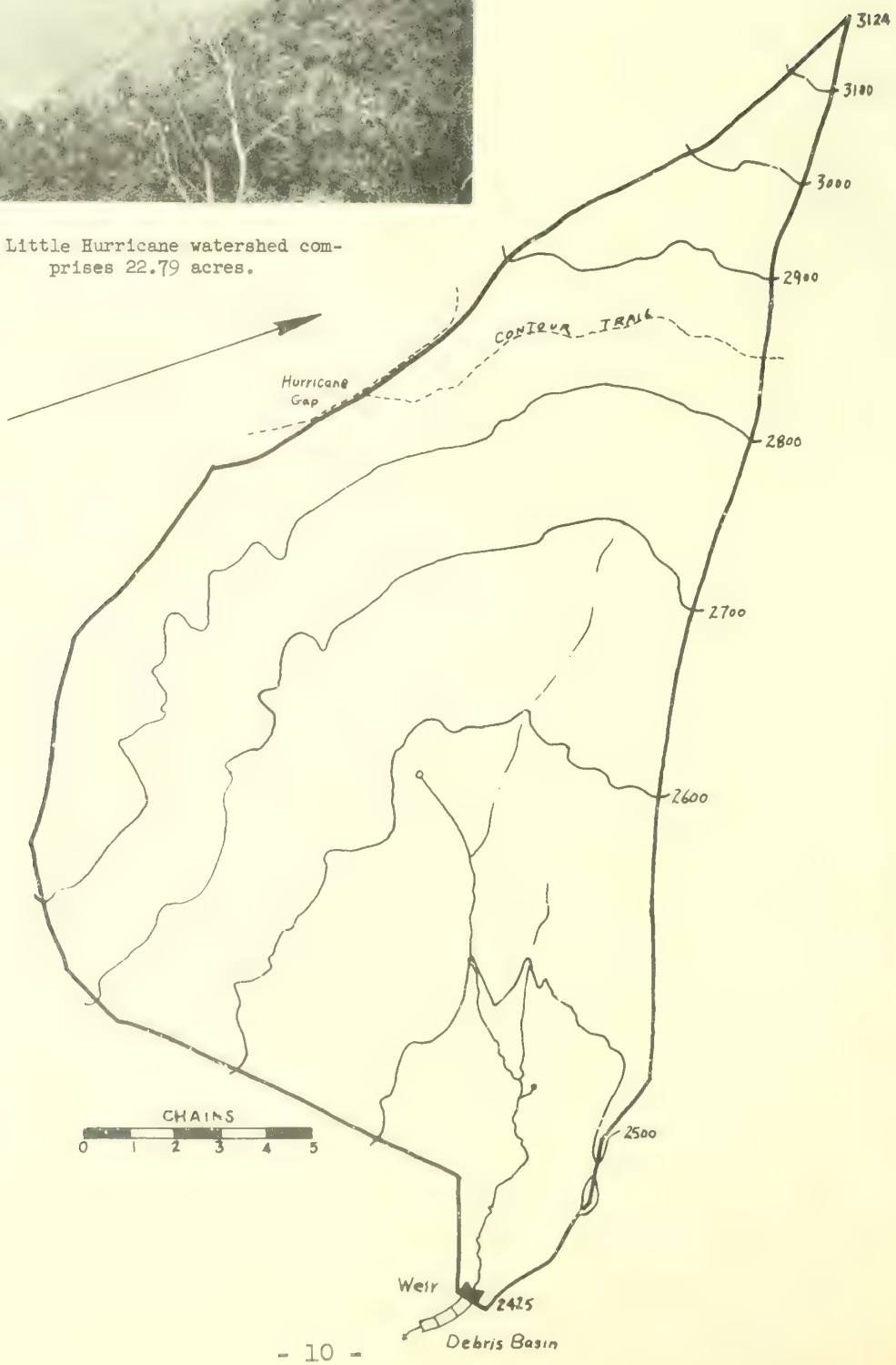

Figure 3.--Clearing operations by CCC enrollees, 1939-1940.

Geology and Physiography

The Little Hurricane Watershed lies in the Blue Ridge province of the Southern Appalachians. The underlying rock is the Archean Carolina gneiss and schist. The thickness of this formation, which was enormous, was greatly increased by complex folding. As a result of folding and the absence of open faults and fractures, there is little likelihood that continuous channels exist to permit the subterranean escape of water through the rock.

The parent material weathers to form a relatively deep soil mantle with bare outcrops of rock appearing only on the steeper slopes at high elevations. Two small outcrops occurring on the upper slopes of the drainage are shown in figure 2.

The topography of the area is steep and rugged. The mean sea level elevations range from 2,425 feet at the base of weir to 3,124 feet at the top of the watershed. The distance from the base to the top is about one-third mile. The land slopes are quite steep with north-south averages 46 percent and east-west averages 58 percent. The mean slope for the watershed is 51 percent and the range is from 10 percent near the bottom to nearly 80 percent at the head of the drainage.

The drainage pattern of the Little Hurricane Branch is dendritic, the stream channel is V-shaped and the slopes are concave, all indicating the youthful stage of the stream. The permanent stream channel is 436 feet long with a drop of 65 feet. The average stream gradient is 14.9 percent.

The ground water table is only slightly less steep than the general slope of the land surface, and at four observation wells ranges from 8 to 16 feet below the soil surface.

Climate[3/]

The climate of the Coweeta area is characterized by moderate temperatures and abundant rainfall. The mean annual temperature is 55°F. and the normal frost-free season extends from April 17 to October 23, a period of 189 days. The average temperature during the growing season is 65°F. Recordings of 90°F. are rare, and summer nights are cool with minimums averaging 58°F. The three coldest months, December, January and February, average 39°F. Periods of cold weather with temperatures below 20°F. are short in duration. The highest and lowest recorded temperatures are 94°F. and -15°F. respectively.

The average annual rainfall over the Coweeta Hydrologic Laboratory is 80 inches and is well distributed throughout the year. For the past 15 years, precipitation has averaged 3.2 inches in October, the driest month, and 7.2 inches in March, the wettest month. The greatest amount of rainfall is received in the southwest portion of the area and the least in the northeast corner. The difference between these two zones is about 20 inches a year.

The average monthly evaporation, measured by a standard U. S. Weather Bureau evaporation pan, varies from 0.98 inches in December to 4.10 inches in May. The average total evaporation for the year is 33.56 inches, or 2.80 inches per month.

Soils

The soils on the watershed are derived from Archean granite gneiss and schist. The parent rocks weather to form a relatively deep soil mantle. A colluvial fill which is more than 20 feet thick occurs on the lower portion of the drainage. On the upper slopes the soil mantle ranges from 5-10 feet in thickness. Two rock outcrops and evidences of an old landslide are present. The lower pasture land shows the effects of former cultivation more noticeably than the areas recently cropped.

Except for the colluvial fill at the base of the watershed, the soils are classified as Porters loam (9).[4/] In the colluvial fill they are Por-

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3/ All climatic values given here are based on 15 years record at weather station #1 (Headquarters area) Coweeta Hydrologic Laboratory.

4/ The entire watershed was mapped by Devereux et al in 1929 as Porters stony loam. After the examination of numerous soil profiles throughout the area and more recent descriptions of the Porters stony loam, Porters loam, and Porters loam colluvial phase, it is believed that the above classification is more nearly correct.

ters loam colluvial phase. The surface soil of Porters loam ranges from 6 to 12 inches in depth and consists of mellow and friable brown loam. The subsoil, to a depth of 20-28 inches, is a red to reddish-brown, friable and crumbly clay-loam. Below this is a reddish-brown mixture of clay loam and disintegrated rock.

Porters loam colluvial phase, is similar in color to typical Porters loam but is much deeper and in some places practically no difference exists between the surface soil and the subsoil. This soil contains a fairly high content of rock fragments which have rolled down from the mountain sides.

According to Devereux et al (9) Porters loam is considered as one of the better agricultural soils of the county. If it occupied more favorable relief, probably all of it would be cultivated, but under existing conditions only a small part is in such use. The principal crop is corn, and yields range from 15 to 40 bushels per acre. Cabbage, potatoes, snap beans, and pumpkins do well also. Porters loam is one of the good pasture-grass soils of western North Carolina. Soils of the colluvial phase are used for the production of corn, cabbage and potatoes, and the yields are about the same as those obtained on typical Porters loam.

Vegetation

Previous to clearing, the primary forest vegetation consisted of second-growth forest of the oak-chestnut type, with cove-hardwood and yellow pine-hardwood types on smaller areas. The scale for the merchantable timber cut on ten acres below the contour trail during clear cutting operations in 1940 is given below (Scribner Decimal C rule with allowance for defect):

Species	Board feet
Pitch pine	2,040
Yellow-poplar	7,750
Black oak	2,310
White oak	420
Chestnut	250
Basswood	590
Red oak	560
Total (141 logs)	13,920

HISTORY OF THE EXPERIMENT

Instrumentation - Installations

Precipitation.--Precipitation or recharge to the watershed is measured by three standard rain gages, numbers 16, 20, and 67. Gages 16 and 20 have been in operation continuously since July 4, 1934. Gage 67 was installed on June 9, 1940 and has been in continuous operation since that date. Previous to the installation of gage 67, measurements from standard rain gage 21 were also applied to the area.

Until June 9, 1940, rainfall intensities were measured by recording rain gage 1, located on the adjacent drainage area No. 7. Gage 10 has been used since its installation on June 9, 1940. Recording rain gage 10 and standard rain gage 67 are located adjacent to each other in order to provide a check against the accuracy of the former.

Charts are changed at least once a week on the recording rain gage and it is completely serviced and checked at least once each year. The standard rain gages are read following each storm or as nearly so as possible. Standard rain gage data are summarized and tabulated by months, hydrologic seasons, calendar years and hydrologic years.

To compute the total precipitation of the watershed, the Horton-Theissen Means method (15) of weighting precipitation is used. Figure 4 shows the geometric division of the watershed for these calculations, as well as the location of the different installations.

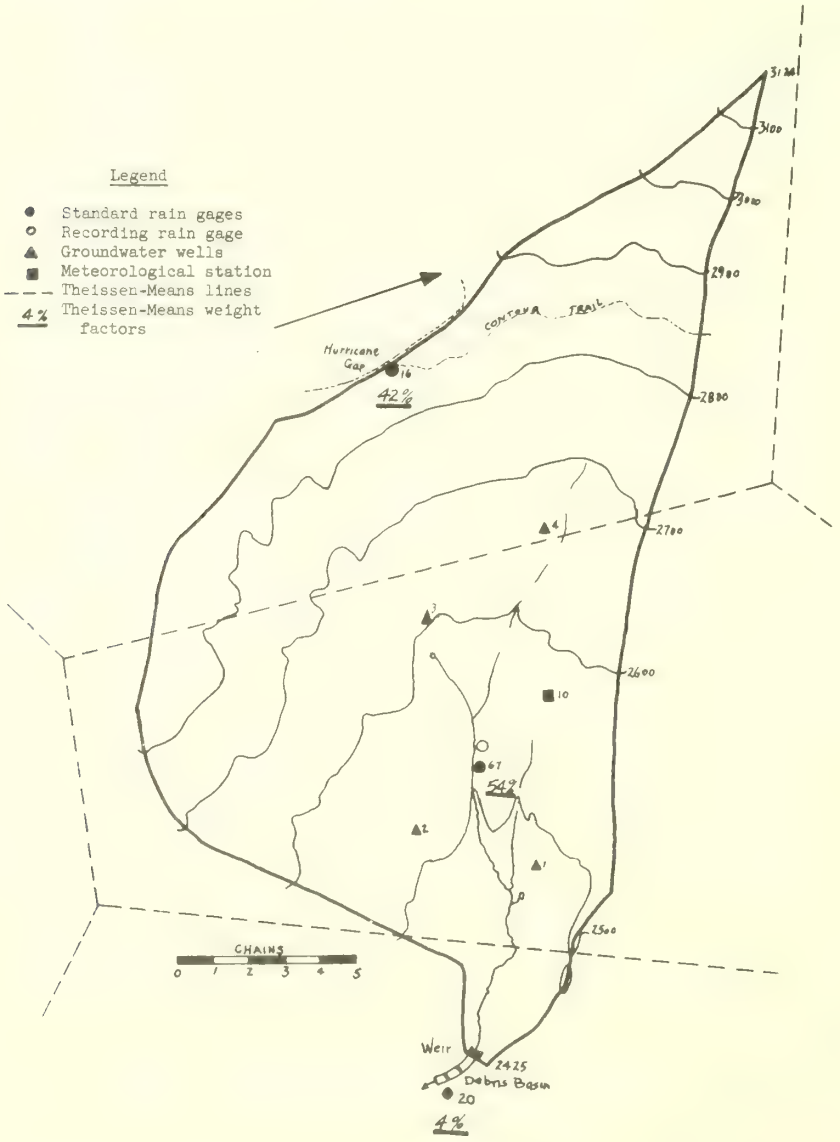


Figure 4.--Installations for measuring water cycle components on the Little Hurricane drainage area.

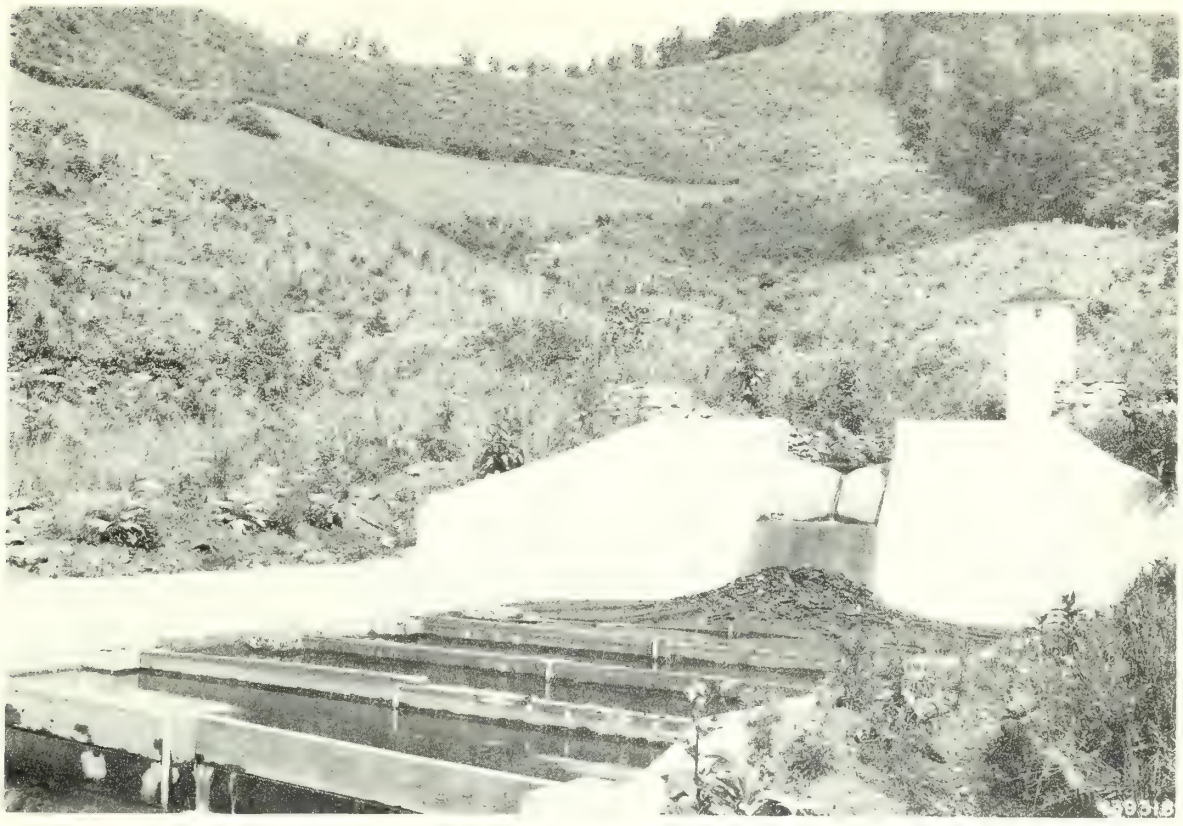


Figure 5.--Columbus deep-notch control for measuring stream flow. At right of weir is the gage house; below is the catchment basin for collecting sediment.

Precipitation intensities are computed from the recording rain gage charts. These data are then tabulated on precipitation intensity records and corrected to agree with the reading of the standard rain gage located adjacent to it. Since the area of the watershed is only approximately 23 acres, a single recording rain gage is used for intensity determinations.

Stream flow.--To measure the discharge from the watershed a 90-degree V-notch weir with a continuous water stage recorder, was installed on July 5, 1934. In order to measure a wider range in stream flow and to accommodate greater debris loads, anticipated as a result of the watershed treatment, the 90-degree V-notch control was replaced with a Columbus CIA deep-notch control in December 1939. Figure 5 pictures the latter stream control. In addition, a concrete stilling well was installed.

To convert the stream-flow data into usable form, the head and time readings are taken from the water level charts and then converted into volume values, i.e., cubic feet per second (c.f.s.) and cubic feet per second per square mile (c.s.m.). For special storm studies, inches per hour is used as well. Volume data are, as in the case of precipitation data, summarized by days, months, hydrologic seasons and years as well as by individual storms. For special storm studies, volume values are plotted over time to give the storm hydrographs.

Water stage recorders are completely serviced and overhauled at least once per year. Recorder charts are changed at least once per week and more frequently when major storms occur.

Soil losses.--In August of 1941 the concrete debris basin shown in figure 5 was constructed to measure soil losses from the watershed. The design of the basin was based upon Stokes Law of the settling velocity of particles in a liquid. The installation consists of three individual basins each with five baffles. The basin obviously catches all but the finest materials as evidenced by the absence of sediment in the stream channel below the installation.

The debris basin is cleaned each spring if required or more frequently in seasons with major storms producing heavy soil losses. Prior to the installation of the debris basin, estimates of soil losses were made from samples taken from the silting basin.

Ground water.--To study fluctuations in the ground water surface, four wells were installed during the summer of 1941. Daily measurements of the water elevations in the wells were made until November 1, 1942. At that time water stage recorders were installed on wells 1 and 2. Weekly measurements of the water levels in wells 3 and 4 were made until April 24, 1944 when, due to a shortage of funds and labor, water level readings in these two wells were discontinued.

Because of the restricted scope of this study no attempt was made to include ground water studies.

Period of Standardization, 1934-1939

On July 5, 1934, a 90-degree V-notch stream control was put into operation along with two standard rain gages (No. 16 and No. 20). A recording rain gage of the float type (No. 1) and another standard rain gage (No. 21) were installed on October 18, 1934 in the adjoining drainage (Hurricane or area No. 7).

On August 3, 1939 the V-notch weir was removed and on December 20, 1939 a modified Columbus type 1-A deep-notch stream control was installed in order to measure a greater range of flows and to accommodate greater debris loads.

The maximum rate of runoff measured before clearing was 110 cubic feet per second per square mile following a rain of 4.67 inches in November of 1938. The maximum intensity of this rain was 2.12 inches per hour.

Before clearing, the rate of sediment movement, based on accumulation in the weir pond, was 9.6 pounds per day.

Clearing Operations, 1940

Logging and clearing operations were started in November, 1939 and were completed in July, 1940. The merchantable timber on the area below the contour trail was sold to a local firm and logged to simulate local practices. The balance of the watershed was cleared by CCC enrollees. On the lower portion, stumps over 16 inches in diameter were pulled and the brush was piled and burned around the larger stumps which remained. On the upper portion the trees were cut and the slash scattered over the ground to form a mulch. About two acres of the area about the contour trail was burned over by a forest fire which occurred on July 2, 1940.

Mountain Farming Treatment, 1941-1951

In the spring of 1941 an area of 5.6 acres was plowed and planted to Hickory King corn (fig. 6). The corn was cultivated by hoe during May and June and the crop of about 23 bushels per acre was harvested in November. If the 1942 season Hickory King corn was again planted and yielded

Figure 6.--Plowing cornfield with single-foot or bull-tongue plow for first crop of corn, April 1940.

over 15 bushels per acre. Hog-proof fence was installed around the cornfield during the season. Golden Prolific corn was planted in 1943 and gave slightly less than 15 bushels per acre. The 1943 season was marked by abundant rainfall and intense thunderstorms. The first notable washing of the cornfield occurred during this season. Due to a lack of funds and labor, the cornfield was permitted to grow up into weeds and shrubs during the 1944 and 1945 seasons. Cattle, however, were excluded from the area. In 1946 the cornfield was cleared of weeds and woody vegetation and plowed again. Hybrid U. S. 13 yellow corn was planted. The harvest was 11.6 bushels per acre. In 1947 and 1948 Hickory King corn was again planted and 800 pounds of fertilizer mixture of 4-10-4 and 4-10-6 were applied. The respective yields for the two seasons were 16 and 14.4 bushels per acre. Figure 7 shows harvesting operations in 1948. In 1949

Figure 7.--Harvesting 1948 corn crop. Yield 14.4 bushels per acre.

Hickory King corn was planted and fertilizer applied for a third time. Due to decreased fertility and numerous intense thunderstorms resulting in soil as well as corn washing, the yield for 1949 dropped to 1 bushel per acre. Since yields had decreased to the point where the cultivation of corn was no longer profitable, the area was converted into pasture following the 1949 season. Figure 8 summarizes the corn yields for the 7 years of record.

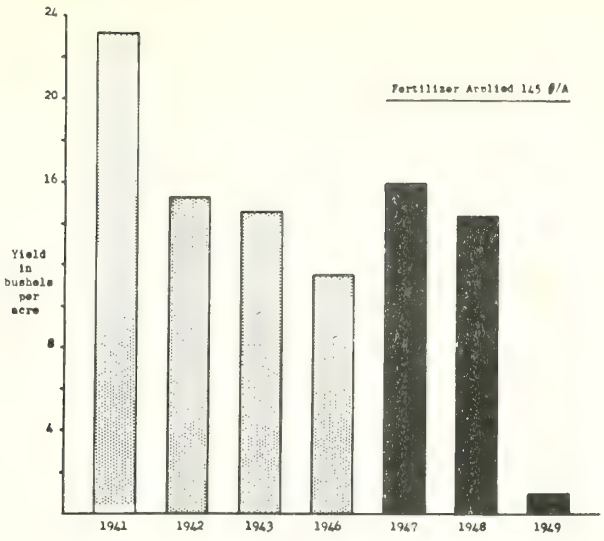


Figure 8.--Summary of corn yields, 1941-1949.

Of the 17 acres outside the cornfield (fig. 9) about 10 acres were too rough or brushy for pasture and were permitted to grow up into coppice forest. One hundred pounds of Cherokee pasture seed mix was sown on the remaining 12 acres in 1942. Competition from trees and shrubs, however, prevented a good catch of grass. Cattle were alternated between this pasture and the adjacent wooded watershed (No. 7). In all there were 336 animal days of grazing on watershed No. 3.

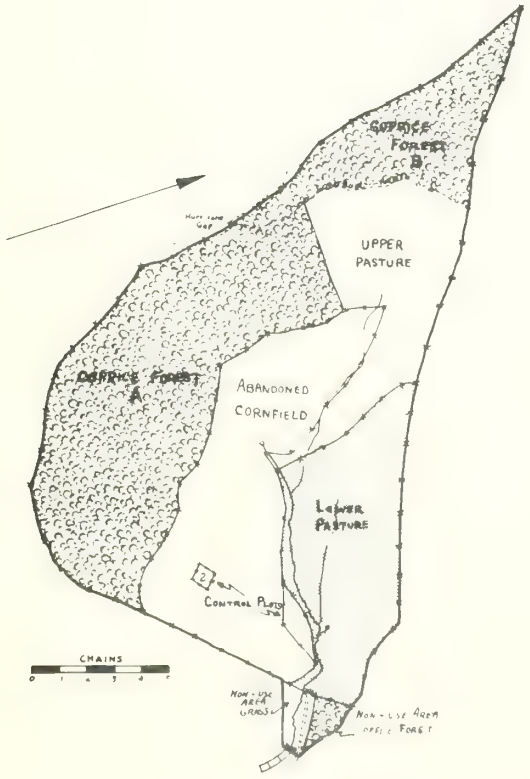


Figure 9.--Map showing the four different types of land use in 1951.

During the 1943 season eight animals were grazed for 67 days. In March 100 pounds of Italian rye grass and red top were sown over the pasture area and in August the sprouts and shrubs below the contour trail were cut back in an attempt to improve the forage. In 1944 a drift fence was built just below and to the right of the recording rain gage to control grazing and to prevent concentration on the lower portion of the pasture. Five head of cattle were alternated between the two portions (designated upper and lower pasture) for a total of 685 animal use days. Nearly all the available forage was consumed in the lower pasture and the soil surface was severely trampled and compacted. During the 1945 season similar grazing use was permitted. In 1946 100 pounds of lespedeza seed were sown over the pastures. The extremely dry weather in August of that year apparently eliminated most of the seedlings established from this planting. The fence between watersheds 3 and 7 was opened and the cattle alternated between the upper pasture of watershed 3 and all of No. 7.

During the 1947 season, cattle were kept continuously on both the upper and lower pastures for a total of 588 days of grazing. In February the woody sprouts on the lower pasture were cut back. An average of four head of cattle grazed continuously on the two pastures in 1948 and were given supplemental feed the last 2 weeks on the area. Similarly, in 1949, four head of cattle were rotated between the upper and lower pastures and were given supplemental feed after August 1.

In 1950 the former cornfield was converted to pasture. The total grazing use in 1950 was 881 animal days. The cattle were periodically rotated between the upper and lower pastures and the abandoned cornfield. During the 1951 season both pastures and the abandoned cornfield were grazed on a rotational grazing system. During August of 1951 the shrubs, weeds, and tree sprouts were cut back, stacked and burned in an effort to improve the pasture conditions.

Soil losses accumulated in the concrete debris basin were measured for the first time on May 28, 1943. Measurements were made thereafter in September 1943, April 1946, April 1947, April 1948, April and July 1949, April 1950, and April 1951. In both 1943 and 1949 numerous intense thunderstorms occurred, necessitating two soil-loss measurements.

The two largest flood flows recorded occurred in 1943 and 1949. On July 30, 1943 a high of 398 c.s.m. was recorded. The maximum flood for the 17-year period occurred on July 10, 1949, when a peak of 1849 c.s.m. was recorded. Figure 10 shows some of the debris carried down by the latter storm. An estimated 76 tons of soil and debris came off the drainage in 30 to 40 minutes during this storm. Figures 10 and 11 indicate the extent of soil displacement during the 1949 season.

During the summer of 1949, surface infiltration studies were started and have been continued to date. Following the harvesting of the 1949 corn crop, two control plots were established and fenced in the cornfield so that vegetative cover changes could be noted.

Figure 10.--Rock deposit in ponding basin, storm of July 10, 1949. Note inlet to stilling well kept clean in order to get record of runoff.

Figure 11.--Soil displacement during the 1949 season.

CHANGES IN SOME BIOLOGIC AND EDAPHIC CHARACTERISTICS OF THE WATERSHED AS A RESULT OF LAND USE

Vegetation Changes

To observe the changes in the vegetal cover on the watershed brought about by forest cutting and mountain farming, a vegetative survey was made in August, 1951. Due to the heterogeneous mixing of the species through the area, no attempt was made to construct a type map. In lieu of a map, the vegetation was observed and identified and its relative abundance was noted according to the different land use elements. Figure 9 indicates the different land uses in 1951.

Coppice forest.--In figure 9 two areas of coppice forest are noted. Coppice forest "A" was cut in 1939-1940 and sprouts have not been cut back. Coppice forest "B" was cut at the same time but sprouts were cut back in 1941. The forest and herbaceous cover of the two areas was so similar in size, density and species composition that they were treated as one. Since a large portion of tree stems were of sprout origin the area was classified as coppice forest.

Except along the ridges, the forest cover was so dense that a ground cover of shrubby and herbaceous vegetation was almost excluded. Along the ridges and in a few openings, greenbrier and wild grape were still abundant. On the slopes, however, these species were much less common, although plant remains indicated that they had been quite abundant there until a few years before. The most common tree species were yellow-poplar, dogwood, sweet hickory, chestnut, red maple, northern red oak, black locust, pitch pine, persimmon, sassafras and black oak. On the ridges pitch pine, white oak and chinquapin were more common and yellow-poplar less abundant than on the lower slopes.

Rhododendron and mountain laurel occurred rather commonly near the ridges and to a lesser degree on the slopes. In the adjacent undisturbed forest areas a moderate understory of these species occurs. Rhododendron and laurel appear to be slow in re-establishing themselves.

The dominant trees were approximately 3 to 3.5 inches in d.b.h. and 12-15 feet in height.

Pastures.--The vegetation of the upper and lower pastures and of the old cornfield is quite similar. Species comprising the present vegetal cover showed no apparent relationship to the vegetative types mapped in 1940. Tree seedlings and sprouts observed in 1951 which were not indicated in the 1940 survey include hawthorn, swamp willow, yellow oak, blackjack oak, green ash, spicebush, yellow birch, black walnut and butternut. The latter two species were probably carried into the area by squirrels or groundhogs. All species observed in 1940, however, were present on the area in 1951.

A much more marked change took place in the shrubby and herbaceous vegetation. Of those species observed in 1940 only nine were found in 1951. On the other hand, a total of thirty-three species were identified

which were not listed as present in 1940. It is significant, too, that many of these invading species, such as yarrow, smartweed, mullein, Canada thistle, nettle and purslane are usually associated with land abuse.

Abandoned cornfield.--As indicated previously, the species composition of the abandoned cornfield is virtually the same as that of the two pastures even though it had been only 2 years since the area was cultivated. The vegetation density of the abandoned cornfield as well as the two pasture areas varied from practically zero on several of the "scald" areas to about 30 to 40 percent ground cover on the best areas. The two control plots indicated in figure 9 were fenced off in 1949 following the harvest of the last corn crop. Cattle have been excluded from these two plots and sprouts have not been cut back. The vegetation here is nearly the same as that of the cornfield in species composition. In the lower plot (No. 1) blackberry and wild strawberry are the two most abundant species. The ground cover in this plot is nearly complete but in spots consists solely of wild strawberry. In the upper plot (No. 2) the same species are represented but the ground cover varies from 65 to 80 percent. It is apparent that in both plots tree species will soon take over. Numerous stems, particularly in the lower plot, are over 6 feet in height.

Trout Habitat

Several studies have been made on the Little Hurricane watershed to show how forest cutting and subsequent mountain farming may change a stream as a trout habitat. Trout are known to be able to withstand a wide range of acidity, alkalinity and carbon dioxide tension. They are, however, quite sensitive to changes in turbidity, stream temperature and siltation.

Turbidity tests comparing the water of the Little Hurricane Branch with that of Bee Branch (a forested watershed) were made from 1946 to 1950. The results of this study indicated that turbidity values for the mountain farm stream were nearly three times as great as those for the forest stream.

Trout are especially sensitive to thermal fluctuations in their environment, particularly when these changes occur near their upper limits of tolerance. During 1948-1949, a stream temperature study was conducted at Coweeta, in which the Little Hurricane Branch was compared with a stream from a forested watershed. Greene (13) reported in 1950 that the weekly maximum temperatures of the farm stream ranged from 9 to 23°F. above those of the forest stream, or an average of 11.5°F. The maximum temperature for the farm stream varied from 65 to as high as 79, whereas the forest stream never exceeded 66, which is considered optimum temperature for brook trout.

Similarly, siltation has been found to be very detrimental to the natural reproduction of trout. The increase sediment load carried by the Little Hurricane Branch following forest cutting and mountain farming is shown in Table 1.

It appears evident then, from the changes in siltation, turbidity and stream temperature on the Little Hurricane Branch that forest cutting and subsequent mountain farming may destroy a stream as a trout habitat.

Edaphic Changes

Many factors, such as climate, vegetation density, type of vegetation, slope, geologic substrata, land use practices and the physical charac-

teristics of the soil combine to determine the stream flow characteristics for a given watershed. The amount of precipitation that goes into stream flow is to a large degree determined by the physical properties of the soil. The characteristics of the plow layer of the soil are strongly influenced by the vegetation it supports. For this reason, any practices which change the nature of the vegetation may in turn bring about changes in the physical characteristics of the surface soil and consequently in stream flow.

One of the most obvious expressions of soil changes is in the degree of soil erosion or in the determination of soil losses from the watershed. Measurements of the soil losses from the watershed have been made since the beginning of the project and are summarized in this section.

Another measure used to determine gross changes in soil characteristics, particularly as they affect water relations, is that of changes in their infiltration rates. Exploratory tests on infiltration were made using the cylinder ring test method in 1949 and 1950 and are summarized in the following pages. During the summer of 1951 a large-scale infiltration study of the entire watershed was commenced. The results of this investigation, however, will not be available for several seasons.

In order to determine more detailed changes in the physical characteristics of the surface soil, soil core and sack samples were collected for analysis. Cylindrical cores 3 inches in diameter by 3 inches long and approximately 1 pint sack samples were collected from the 0-3 and 3-6 inch layers from six sites. Five samples were collected from each of the following sites from both layers: undisturbed forest (from control plots in adjacent watershed, same soil type), coppice forest, upper pasture, lower pasture, abandoned cornfield, and control plots within the old cornfield. The sampling plots were randomly selected from numbered grid cross-sections except from the control plots in both the undisturbed forest and the abandoned cornfield. The latter were stratified at right angles to the contour.

From the sack samples mechanical analyses and organic matter determinations were made. The core samples were used to measure permeability, capillary, noncapillary and total porosity, volume weight, and aggregate analyses. The results of these various determinations are presented in the following pages.

Soil losses.--As indicated previously, soil losses since 1941 have been measured using the specially designed debris basin. Prior to the installation of the debris basin, soil losses were measured from deposits in the silting basin. In making these measurements, the water is allowed to pass over the weir blade before it is diverted into a trough which bypasses the debris basins, thus providing a continuous record of stream discharge. Samples of two hundred cubic centimeters of sediment are taken from each baffle within each of the three debris basins after the sediments have dried. Following volume measurements in each baffle, the debris is removed. The total soil losses are then computed from the dry weight of the samples and from the volume measurements applying to each division of the basin.

The total soil losses measured from the inception of the experiment on July 5, 1934 to the measurement made on April 11, 1951 are summarized in table 1. It is apparent that soil losses have increased tremendously following the treatment of the watershed. The actual increase amounts to over 12 times as much soil loss per acre per year. Before the installation of the debris basin (watershed in forest cover until the winter of 1939-1940) the total soil loss amounted to 1081 pounds per acre or 154 pounds per acre per year. A portion of this amount can be attributed to the treatment, since the debris basin was not installed until nearly two years after the clear cutting of the watershed was started. Since the installation of the debris basin, an average loss of over 1900 pounds or nearly 1 ton per acre per year has been measured. The maximum loss was measured in 1949, when precipitation ranged well above average. For the 93-day period from April 9 to July 11, a total loss of 185,875 pounds, or an average of nearly one ton per day was measured for the entire area.

Table 1.--Summary of soil losses

Period	No. days	Treatment	Total loss, dry weight	Average loss per day	Average loss per acre per year
			Pounds	Pounds	Pounds
7/3/34 to 8/27/41	2557	Forest cover and initial treatment	24,637	9.6	153.7
8/28/41 to 5/4/43	644	Corn, pasture	13,928	21.6	345.7
5/5/43 to 9/8/43	126	Corn, pasture	79,058	627.4	10,043.9
			Average	118.1	1,890.6
9/9/43 to 4/16/46	1185	Fallow, pasture	44,085	37.2	595.5
4/17/46 to 3/28/47	345	Corn, pasture	13,507	39.2	627.5
3/29/47 to 4/13/48	381	Corn, pasture	16,186	42.5	680.0
4/14/48 to 4/8/49	359	Corn, pasture	32,879	91.6	1,466.4
4/9/49 to 7/11/49	93	Corn, pasture	185,875	1,998.6	31,995.1
			Average	210.9	3,377.7
7/12/49 to 4/10/50	272	Pasture	42,330	155.6	2,491.0
4/11/50 to 4/11/51	365	Pasture	21,361	85.5	936.5
			Average	100.0	1,600.8
		Total soil loss 8/28/41 to 4/11/51			449,209 pounds
		Average loss 8/28/41 to 4/11/51			1,933 pounds per acre per year

As indicated previously, an estimated 76 tons of soil and debris came off the watershed in a period of 30 to 40 minutes during the storm of July 10, 1949, when a record peak of 1849 c.s.m. was recorded. Figure 10 indicates the magnitude of soil losses resulting from this storm.

These data indicate that the greatest soil losses were sustained while the cornfield was under cultivation. From September 1941 to September 1943, the average soil loss amounted to nearly 1 ton per acre per year. Following this period, the cornfield was permitted to lie idle until the 1946 season. The pastures, however, were grazed. A decrease to approximately 600 pounds per acre was noted for this period. Soil losses mounted to over 2-1/2 tons per acre per year for the period from 1946 to 1949 when the cornfield was again cultivated. After the 1949 season the cornfield was converted to pasture. Two fenced, ungrazed enclosures were installed as controls (fig. 9). A decrease to 1,600 pounds per acre per year in soil losses was noted from August 1949 to April 1951.

If the losses from the various land-use divisions of the watershed could be analyzed separately, it would undoubtedly be found that by far the greatest percentage of the total loss was contributed by the cornfield and the lower pasture. Evidence indicating this is found in the numerous scalds in the cornfield and the lower pasture where topsoil has been completely removed and the red subsoil exposed.

On several occasions during the 1951 season, storms which produced peak discharges of less than 5 c.s.m. were observed to produce turbid overland flow in the abandoned cornfield and in the lower pasture. In 10 years of field observations during and following storms, overland flow or evidence of overland flow has never been observed in the coppice forest area.

Infiltration.--A surface infiltration study made on the watershed in July, 1949 demonstrated how the small, heavily trampled area of the lower pasture might be the source of a large proportion of the total storm runoff.

To measure the infiltration rate, a steel cylinder 10 inches in diameter and approximately 6 inches in height was driven into the ground for a depth of several inches. Two area inches of water were poured into the cylinder and the time required for the water to disappear from the soil surface was noted. The values thus derived were converted to inches per hour infiltration. Infiltration rates were as follows:

Land-use	Infiltration rate per hour (Inches)
Channel area	.0
Lower pasture	0.56
Upper pasture	3.00
Cornfield	4.00
Coppice forest	6.00

Before grazing started on the abandoned cornfield in 1950, a similar infiltration study was made over the entire area and was repeated after each period of rotational grazing. Data in the following table show that it does

not require many animal use days to decrease the ability of the soil to take in water. Changes in infiltration rate were as follows:

	Infiltration rate per hour (Inches)
Before grazing	3.02
After 15 animal-use days per acre	1.55
After 30 animal-use days per acre	0.62

A similar surface infiltration study was begun in 1951. The entire watershed was gridded and monthly infiltration tests were made during the summer months on more than one hundred plots. These observations are to be continued for several seasons and the data are to be used as the basis for a special investigation on infiltration.

Mechanical analysis.--The objective of a mechanical analysis is to determine the size distribution of the individual particles within the soil. These results may be expressed by soil texture. Soil texture, other things being equal, influences the amount of surface area of the soil particles, which in turn affects the water-holding capacity of a soil. Retention storage, or water held in the capillary pores of mineral soils against the pull of gravity, is greater in silts and clays since the surface area exposed to water is many times greater than in sands. On the other hand, a high content of sand frequently provides greater opportunity for the development of large non-capillary pores and thus increases detention storage.

In preparing the samples for the mechanical analysis, the larger clods and aggregates were broken down and the entire sample placed on a 2 mm. sieve. The weight of the material which remained on the sieve after shaking, was noted. This material consisted largely of pebbles, rock fragments, and concretions. From these weights and from the total weight of the sample, percentages were calculated. To determine the mechanical composition of the portion of the samples passing through the 2 mm. sieve, the Bouyoucas (8) hydrometer method of mechanical analysis was employed.

From the results of these analyses it appears that the treatment applied to the watershed has not effected any large scale changes in the mechanical composition of the less than 2 mm. fraction of the soil. There is little variation indicated in either soil layer among the average values for each site. The undisturbed forest and the coppice forest show the highest content of sand, and the coppice forest has the lowest values for fine clay. The pastured areas are lowest in sand content and highest in fine clay. In view of these results, the two forested areas should show higher detention storage and lower retention storage than the pastured areas. The samples for the cornfield indicated intermediate detention and retention values between the pasture and the forest.

If, however, the materials greater than two millimeters in diameter have an influence similar to sand, then the undisturbed forest might be in a less favorable situation since it contains much less of this coarser fraction than any of the other plots.

Aggregate analysis.--One of the primary objectives of an aggregate analysis is the determination of the extent to which the finer mechanical separates are aggregated into coarser fractions. An aggregate analysis thus provides a measure of soil structure. Soil-water relations and aeration conditions are both strongly influenced by soil structure. The total percentage of aggregates or "state of aggregation" as suggested by Baver (6), gives a good indication of the erodibility of soils. If, for example, the state of aggregation is high, i.e., the soil contains a high content of water-stable aggregates, susceptibility to erosion is considerably lower than in the case of low aggregate stability. In the latter case there is little binding together of the particles into granules, and, consequently, falling raindrops and surface flow tend to disperse the soil. Under such conditions the soil takes up water more slowly and is obviously highly erosive.

In making aggregate analyses of the samples used in this study, Yoder's (30) dunker or wet-sieving method was employed. The five oven-dry core samples from each site and each layer were mixed and two composite samples extracted. Aggregate analyses were then made on the composite samples.

The results of this analysis indicate that the treatment of the watershed has effected a marked change in the stability of soil aggregates and consequently, soil structure. In both the surface and subsurface layers, but particularly in the surface, the undisturbed forest shows a considerably higher content of water-stable aggregates greater than 2 mm. in diameter than all other sites except the coppice forest. Even here, in the surface layer a difference of over 10 percent exists. These differences are particularly significant when one considers that the undisturbed forest contained much smaller quantities of coarse material (sand and particles 2 mm. in diameter or larger) than the other sites studied.

An analysis of the degree of aggregation in the fine earth material indicated similar results, with the forested areas showing even higher aggregation here than in the case of total water-stable aggregates.

From field observations the greatest part of the soil loss from the watershed is obviously from the cornfield and the lower pasture. The changes in aggregation or structure of the surface soil have no doubt contributed materially to these differences in soil losses. The marked changes in soil structure as indicated by aggregation further contribute to the changes in permeability and consequently to runoff characteristics which are noted later.

Soil organic matter.--The presence of a high content of organic matter in a soil has a marked influence on the storage capacity that a soil has for water. Detention storage, i.e., water detained temporarily in the large noncapillary pores, is increased by the inclusion of organic matter because of its influence on soil structure. Decaying roots and greater biological activity also result in the formation of the large hydraulic pathways which channel water through the soil profile and eventually to ground water.

Similarly, retention storage--that water retained or held in the soil and made available for plant growth--is usually increased through the incorporation of additional organic matter. Organic matter has a high moisture-absorptive capacity. In the colloidal state it takes up as much as 4.4 times its own weight of water. When decomposed and mixed with the soil, it coats

the soil particles with a gel-like porous and highly adsorptive substance. Clinging to the particles, this material, in effect, increases their surface areas and thus their storage capacity.

In this study, a determination was made of the organic matter contained in the samples collected from the watershed. In making these determinations, the dry combustion method patterned after the work of Schollenberger (21) was employed, i.e., measuring the amount of carbon dioxide evolved in the combustion of the soil and converting the carbon dioxide content into percent organic matter using a conversion factor of .471. The results of this analysis are given in table 2.

Table 2.--Summary of physical characteristics of the soil

Site	Volume weight	Total porosity	Capillary porosity	Non-capillary porosity	Permeability	Organic matter content	Sand and coarser material	Aggregates over 4mm.
		Percent	Percent	Percent	In./Hr.	Percent	Percent	Percent
0-3 inch layer								
Undisturbed forest	0.88	56.8	36.1	20.7	171.1	7.03	81.7	85.5
Coppice forest	.82	60.5	36.0	24.5	163.0	8.97	91.4	78.2
Upper pasture	1.03	53.9	39.0	14.9	20.2	7.62	99.6	64.1
Lower pasture	1.11	52.5	37.9	14.6	6.6	4.00	97.7	55.9
Cornfield	.93	56.1	40.1	16.0	12.4	4.40	99.1	59.0
Control plots (cornfield)	.98	53.8	29.2	24.6	85.0	7.28	91.0	46.2
3-6 inch layer								
Undisturbed forest	1.05	54.9	32.6	22.3	64.2	4.87	82.8	73.8
Coppice forest	.98	57.1	37.0	20.1	94.7	5.51	97.4	63.5
Upper pasture	1.07	56.2	37.7	18.5	16.9	4.41	95.8	48.6
Lower pasture	1.28	50.5	35.4	15.1	2.7	2.43	90.4	56.7
Cornfield	1.06	56.1	40.5	15.6	8.9	4.98	97.6	62.2
Control plots (cornfield)	1.06	51.0	37.9	13.1	64.0	4.62	89.9	40.1

In the surface layers, all areas except the lower pasture and the cornfield show values greater than 7 percent organic matter. This is probably the result of contributions to the litter by the slash accumulation and the heavy herbaceous cover following clear cutting. Similarly, the upper pasture and the control plots in the abandoned cornfield show a higher content of organic matter than the undisturbed forest. In the case of the upper pasture, this is possibly due to minimum usage by cattle, heavy herbaceous and shrubby ground cover, and to the fact that the vegetation is cut back or sprouted periodically, thus increasing the amount of litter accumulated on the soil surface. The high average value for the control plots in the cornfield is apparently the result of two seasons abandonment, permitting the development of a good ground cover and consequent litter accumulation. For the surface layer, this value is considerably higher in comparison with the cornfield, which has been grazed since abandonment. In the subsurface layer it is noted that the values for the two areas are approximately equal.

In comparison, the lower pasture and the cornfield show values considerably lower than the undisturbed forest and less than half the content of the coppice forest. The results of row cropping and overgrazing are thus apparent in the differences in soil organic matter.

In the subsurface layer, 3-6 inches, all values are lower by 1-1/2 to over 3 percent than in the surface layer, except in the cornfield, where the similarity of organic content in the two layers is the result of their mixing by the recent plowing and cultivation. The subsurface layer of all plots, except the lower pasture have similar organic contents. The organic content of the subsurface layer of the lower pasture is only about one-half as great as in the other plots. This difference together with the lower content of organic matter in the surface layer of this area as compared to the upper pasture indicates differences in the soils of these areas that are not entirely due to current management differences.

Porosity.--Soil porosity is undoubtedly one of the most significant of all physical soil properties in hydrologic studies. From a hydrologic standpoint, the primary function of a soil is that of a storage reservoir. This storage reservoir acts in the same fashion as a large dam project. In the case of floods on dam-protected streams, the flood waters accumulate first in the reservoir. After satisfying the initial storage in the reservoir, the water continues to accumulate in the overflow reservoir storage and is detained temporarily until it can be safely released to the stream below. Following the storm period the temporary storage is released as rapidly as possible until normal storage capacity is reached. The water left in the reservoir is retained and released slowly for use as irrigation water, for power generation, municipal supply and other uses.

A good soil reservoir should act in the same manner. The storage capacity of a soil or its pore volume is divided into two classes, capillary and noncapillary. The noncapillary pores consist of those spaces between the soil particles or soil aggregates that are so large that absorption and film forces cannot retain all the water in them against the pull of gravity. Thus, water is held in them only temporarily, similar to the overflow reservoir. Such storage is termed detention storage by the hydrologist.

The small capillary pores in the soil provide the hydrologist's retention storage. Water in the capillary or retention storage reservoir is held against the force of gravity but is subject to the pull of evaporation near the surface of the soil and to transpiration at any depth where living roots occur. Part of the water thus retained in the soil is utilized by plant growth or is dissipated from an area by evaporation. This retention storage reservoir in the soil acts as the normal reservoir of a river system.

To determine the porosity values for the samples used herein, the 3 x 3 inch soil cores were saturated, weighed and placed on a tension table for approximately 24 hours at a tension of 40 centimeters. The weights were recorded and these values were used in determining noncapillary or detention storage. After weighing, the samples were oven-dried at 105° C. and reweighed to determine capillary or retention storage as well as volume weight. The average values obtained for noncapillary, capillary and total pore space are presented in table 2.

Volume weight.--Volume weight may be defined as the ratio between the dry weight of a given mass of undisturbed soil and its volume. The usual method of determining volume weight, or, as it is frequently termed, the apparent specific gravity or bulk density, is to divide the oven-dry weight of the undisturbed soil in grams by the volume of space which this soil occupies in cubic centimeters.

The volume weight of a soil is dependent for the most part on structure and organic matter content. Ordinarily, very compact soils with low pore volume and low aggregation possess high volume weights. On the other hand, porous, well aggregated soils show low volume weights. Similarly, soils with a high content of organic matter have a lower specific gravity as well as a lower volume weight than those with a low content of organic matter. Forest soils, because they usually have a higher content of organic matter, show lower volume weights in their surface layers than grazed or cultivated soils.

In determining the volume weights, the oven-dry weight of the soil core in grams was divided by the volume of the core in cubic centimeters. Where soil cores were not full, volume corrections were made by filling the depressions with sand and then measuring the volume of sand utilized. Table 2 shows the average values for the six sites for both the surface and subsurface layers.

The average results given in table 2 indicate that in the surface layer both the undisturbed forest and the coppice forest areas have more favorable soil-water relations than the other areas. The highest values in both the surface and subsurface layers were found in the lower pasture. In the subsurface layer, although the two forest areas show slightly lower values, the variations are small except for the lower pasture. As might be expected, all values for the subsurface layer are somewhat higher than in the surface layer of the same area. The results tend to indicate a poorer physical condition of the surface layers in the lower pasture, which would substantiate field observations on surface runoff conditions.

Permeability.--The permeability of a soil is ordinarily considered to be the rate at which water moves through the soil column. It differs from

infiltration in that the latter is concerned only with the rate at which water enters the soil. It is evident then that infiltration and permeability together provide important measures of physical soil characteristics from the standpoint of surface runoff phenomena. A soil may have a high infiltration rate and a low permeability rate or the permeability rate may be high and a "surface bottleneck" may be present, giving a low infiltration rate. In either case, or if both values are low, comparatively little water can be stored and transmitted through the soil, and high surface runoff results.

Since soil moisture deficits must be satisfied before water starts permeating or percolating through the soil column, permeability determinations were made on saturated soil cores. As nearly as possible a 1/2-inch head of water was maintained on the soil core for a period of 1 hour. The permeability rate was determined by measuring the amount of water which percolated through the soil core in that time. In extremely permeable cores 1/2 hour was used and the resulting values doubled. The results of these determinations are shown in table 2.

Permeability tests show much greater differences in the different land use areas than the other physical soil analyses. Both forested areas show very high permeability rates in both the surface and subsurface layers. The upper pasture, cornfield and, particularly, the lower pasture show very low rates in comparison. The rates indicated for the control plots approach those of the forested areas, which apparently reflect the effects of 2 years of abandonment. By far the lowest rates in both layers are those for the lower pasture, undoubtedly the result of overgrazing with its consequent compaction.

According to Baver (6), Lassen, Lull and Frank (18), and Fletcher (11), permeability or percolation is dependent upon the noncapillary pore volume. As indicated previously, noncapillary porosity decreased as a result of the treatment to the watershed although the decrease was only in the magnitude of approximately 6 percent. Assuming that noncapillary pore space determined permeability, from these data it appears that relatively small changes in this pore volume may effect very marked changes in the permeability rate.

The values noted for the infiltration rate indicate a trend similar to that for the permeability rate. The changes indicated for both the infiltration rate and the permeability rate indicate a close relationship with the changes in surface runoff noted in the sections which follow. However, the fact that infiltration rates were much lower than permeability rates shows that the immediate surface of the soil is the limiting factor in moisture detention and is causing increased surface runoff on the Little Hurricane Watershed.

HYDROLOGIC DATA

The basic data in nearly all hydrologic investigations are measures of precipitation, or recharge, and stream flow, or discharge. The volume and rate of discharge from a given watershed or hydrologic unit is a reflection of the amount and intensity of precipitation which it receives and the characteristics of the watershed. The manner in which these factors are

measured on the Little Hurricane Watershed and the methods employed in converting the raw data into usable form have been noted previously.

Precipitation

The total weighted precipitation received by the watershed, as measured by three standard rain gages servicing the area, is summarized by hydrologic years in the following tabulation. The hydrologic year runs from November to October. Data for 1934 and 1951 are incomplete.

Hydrologic year	Precipitation (Inches)
1935	61.94
1936	84.84
1937	72.85
1938	63.72
1939	74.76
1940	56.79
1941	50.33
1942	67.81
1943	77.70
1944	66.64
1945	65.21
1946	79.13
1947	69.00
1948	71.08
1949	107.18
1950	76.22
Average	71.54

Figure 12 indicates the average monthly precipitation as well as the area inches of stream discharge by months and by hydrologic seasons. Precipitation, vegetation, and soil conditions are all reflected in the discharge curve. From January through March precipitation is at its maximum. Evaporation and transpiration are at a minimum and soil moisture conditions are at their peak. Much of the precipitation which occurs during these months filters rather rapidly through the soil reservoir into ground water, since soil moisture deficits are very low. Consequently, stream discharge is at its highest level. A large portion of the water appears as clean, non-turbid water from subsurface and ground-water flow. The majority of the storms during this season produce low-intensity precipitation and some snow, which ordinarily does not accumulate to great depths to form flood hazard conditions.

Throughout April and continuing into May, precipitation steadily declines. At the same time vegetation commences growing, temperatures increase and consequent losses to evaporation and transpiration also increase. Starting in May and continuing throughout June and part of July, precipitation increases rather sharply. Likewise, evaporation and transpiration are increasing and the discharge curve indicates only a slight rise as a result of the increased precipitation. Starting in July and continuing through October, precipitation steadily declines as evaporation and transpiration continue to make heavy demands. This is indicated in the discharge curve, in that stream

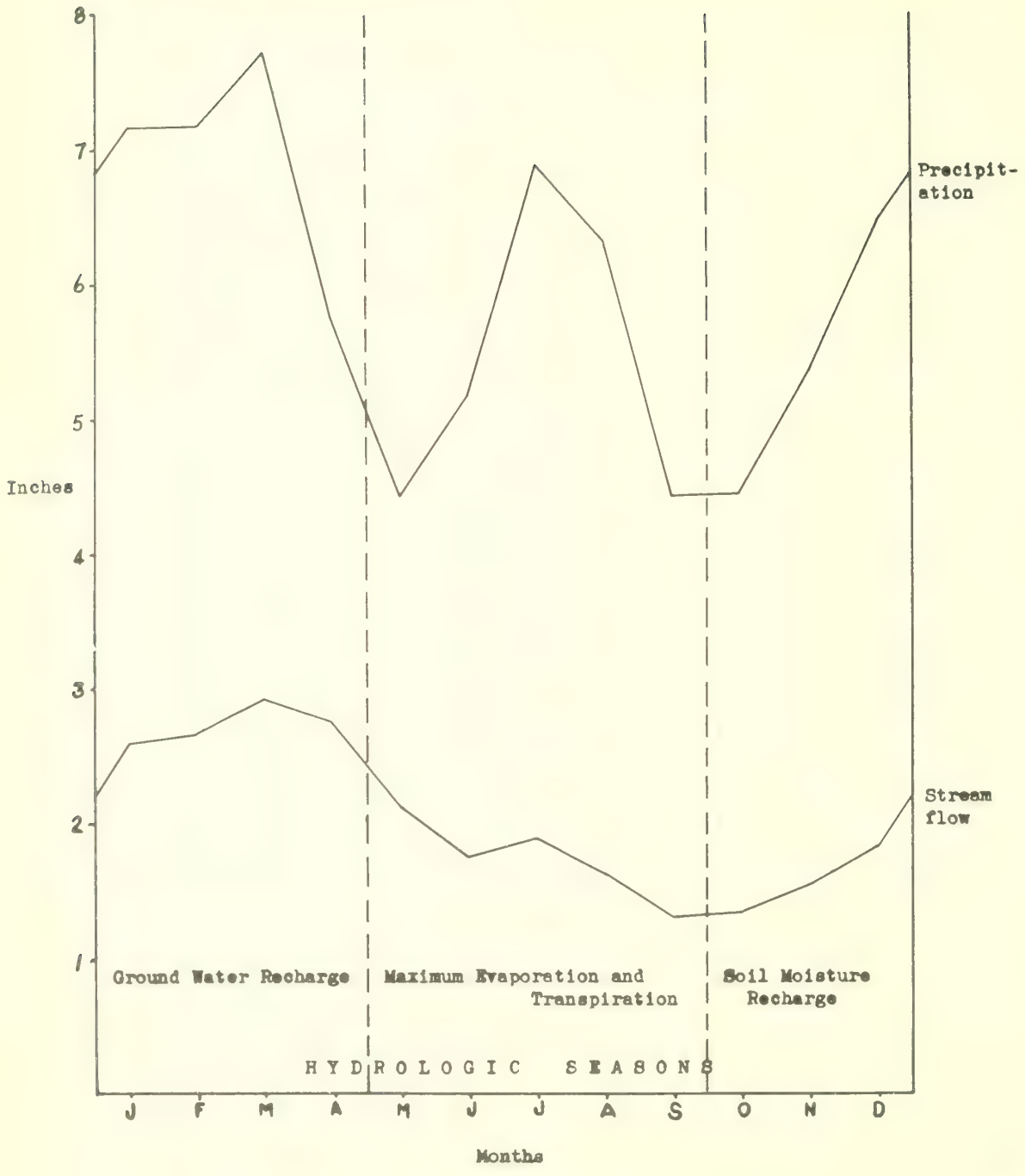


Figure 12.--Average monthly precipitation and stream flow.

discharge is at its lowest ebb during September.

October marks the end of the growing season and with it comes a sudden decrease in both evaporation and transpiration. At the same time the precipitation curve swings sharply upward. Stream discharge shows a gradual climb until the soil moisture deficits resulting from the heavy use by vegetation and evaporation are satisfied. The cycle is completed in the winter months when soil moisture deficits are met and ground water recharge again occurs.

In studies of individual storms and their effects on stream discharge, a measure of precipitation intensities as well as a measure of total amounts are required. Recording rain gages 67 and 1 were used to obtain precipitation intensities. The precipitation intensity values as well as the mass or accumulated precipitation values are taken from the precipitation intensity records and are shown graphically along with stream discharge for representative storms used in this study in figures 13 and 14.

An examination of individual storms shows that prior to treatment bursts of precipitation usually resulted only in a continued steady increase in stream flow. Following the clear cutting of the forest and the initiation of mountain farming, relatively small bursts of precipitation resulted in immediate and sharp increases in stream flow. The treatment of the watershed has thus resulted in producing stream flow of extremely "flashy" characteristics.

Stream Flow

Gage height readings recorded for the weirs used in measuring discharge from the watershed are converted to cubic feet per second from rating tables calculated for the respective stream controls. Since precipitation is expressed in inches and in inches per hour, the cubic feet per second values were converted to inches per hour to aid in graphic presentation and analysis. The discharge values in inches per hour were plotted over time to give the storm hydrographs for individual storms. Hydrographs for representative storms used herein are given in figures 13 and 14.

Definition of Storms

Frequently, precipitation is received in such small amounts and at such low intensities that it produces no perceptible change in the stream hydrograph. All or the greater part of it may be intercepted by vegetation. Sufficient precipitation must occur to satisfy initial depression storage (water required to fill the small depressions on the soil surface) as well as vegetation interception before it can run off or otherwise enter the stream. Many small rises in stream hydrographs following a brief low-intensity period of precipitation are caused by precipitation falling in the channel or stream itself rather than by surface runoff or some form of subsurface flow. Unless an investigation is concerned with total water yields, the inclusion of all periods of precipitation is impractical. Consequently, for individual storm studies, there must be some dividing line or definition of what constitutes a storm.

After examining all the precipitation and stream-flow data, the arbitrary standard of a maximum 30-minute intensity of at least 0.90 inch per hour was selected. An exception was made in one case in which the maximum 30-min-

ute precipitation intensity was less than 0.90 inch per hour where the peak stream discharge greatly exceeded "normal" for the amount and intensity of the precipitation received.

Classification of Storms

Streams, particularly from small watersheds, respond quite differently to different storms. Consequently, based upon the patterns of precipitation and the stream hydrographs resulting therefrom, all storms were classified naturally into three categories: summer, winter, and intermediate. Summer storms are characterized by short but intense periods of rainfall. They are usually occasioned by frontal activity or convection storms. Summer storms are further subdivided into unit or single storms and multiple storms. The unit summer storm yields nearly all of its precipitation in bursts which are bunched closely together, and produces a single peak on the hydrograph. The multiple summer storm produces intense precipitation bursts which are separated by a period of time not exceeding 6 hours, in which precipitation may stop entirely or be of low intensities. A hydrograph of two or more peaks results. Graphs A and B in figure 13 show the precipitation patterns and the resultant hydrographs of the unit and multiple summer storms respectively.

The intermediate storm is characterized by precipitation which comes alternately in short intense bursts followed by periods of precipitation of more moderate intensities. It usually yields a greater amount of precipitation than most summer storms and is usually associated with the spring and fall seasons. The tropical hurricanes which reach this area fall into this classification. The hydrographs produced by such storms are marked by a series of peaks and troughs. Graph C in figure 13 illustrates a typical intermediate type storm.

The winter storm gives a relatively large volume of precipitation which usually does not come at the higher intensities associated with summer storms. However, the winter storm is usually of much longer duration as it is most frequently the result of cold front activity. Graph D in figure 13 illustrates the precipitation pattern and the hydrograph of a characteristic winter storm.

Distribution of Storms

An analysis of a listing of storms producing peak flows exceeding 9 cubic feet per second per square mile made by Johnson[5/] and continued through August, 1951 by the writer, indicates that from the standpoint of the distribution of flood-producing storms, the summer storm is the most significant (fig. 15). Similarly, 12 of the recorded 14 flood peaks which exceeded 100 c.s.m. resulted from summer storms.

5/ Johnson, E. A. Summary of Flood Peaks over 9 c.s.m., Watershed No. 3, 1949 (unpublished compilation, Coweeta Hydrologic Laboratory).

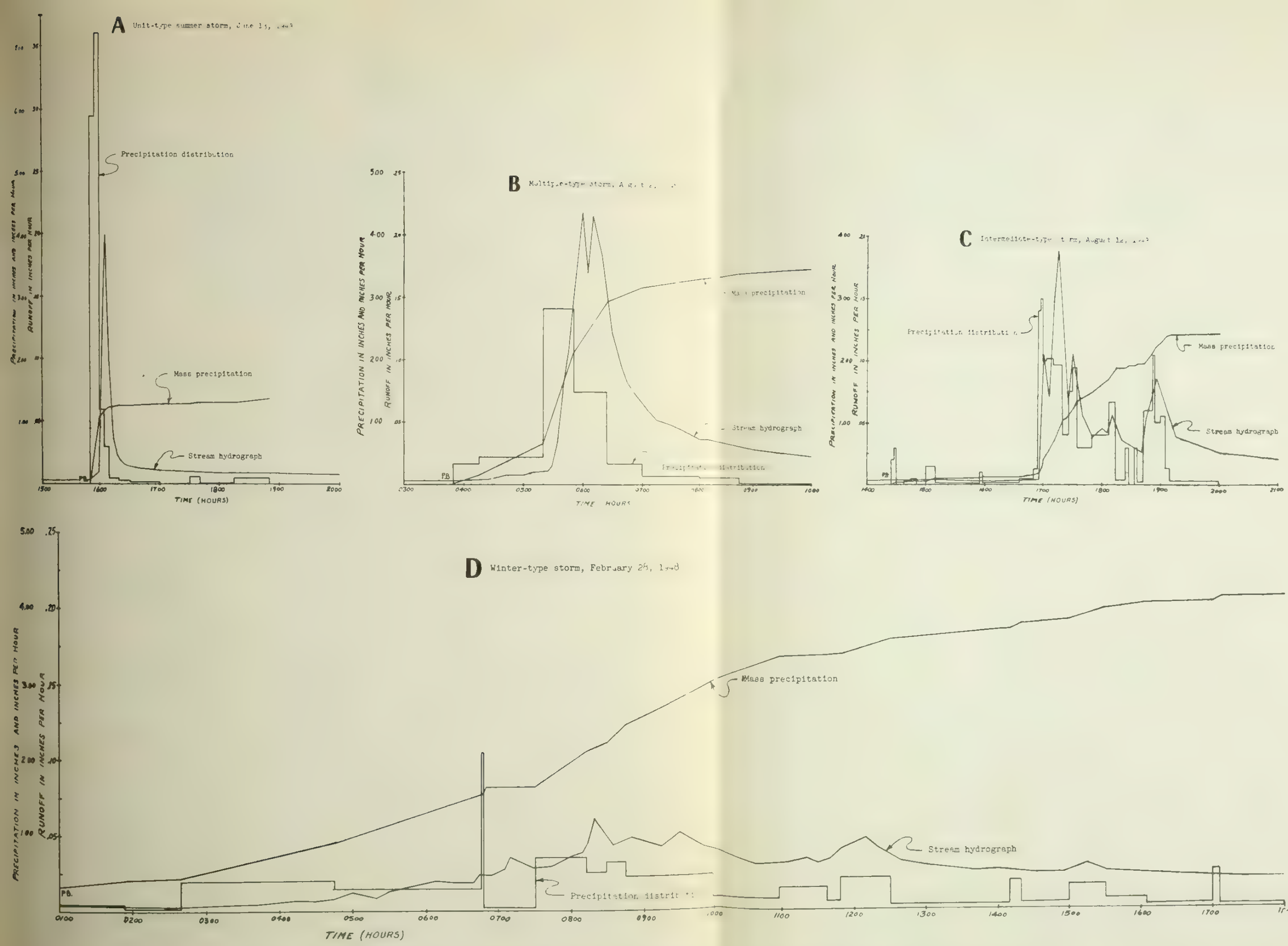
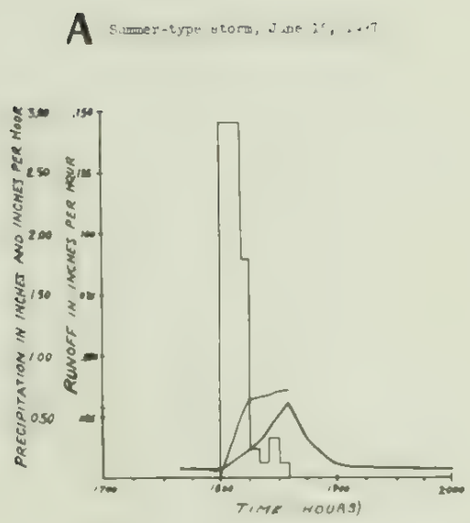
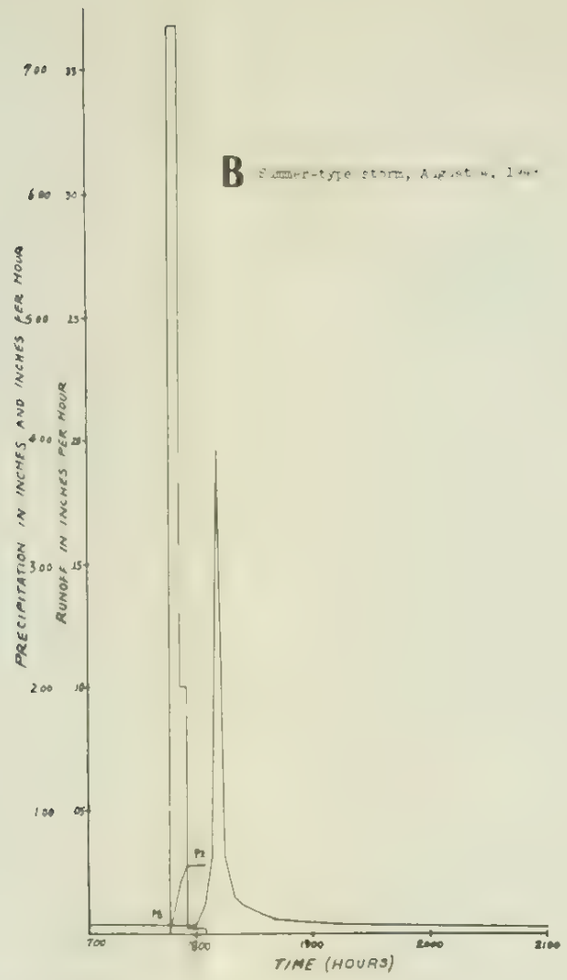
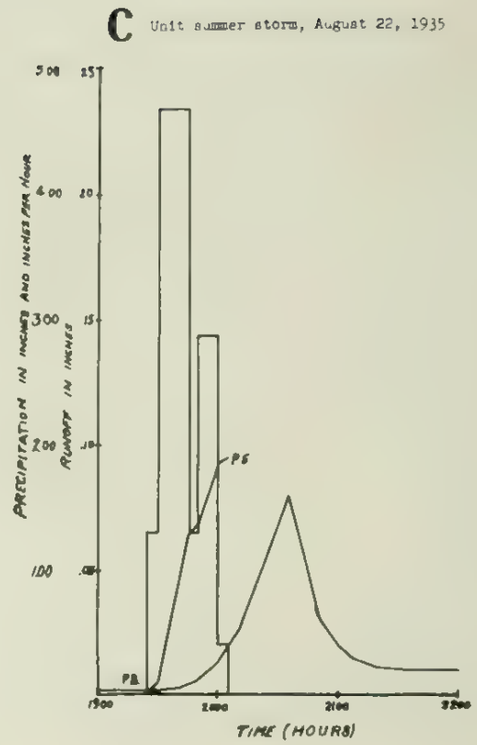
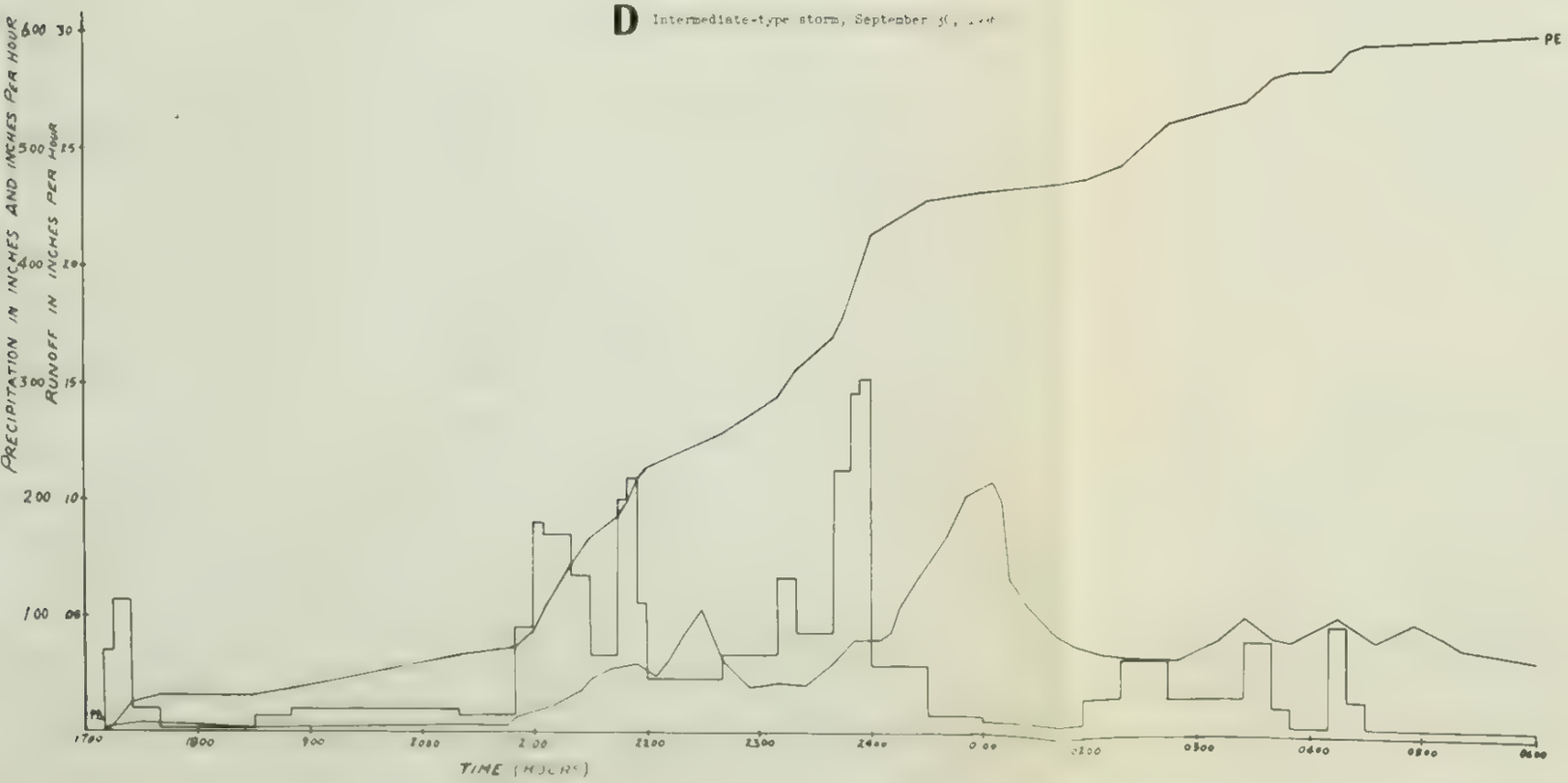


Figure 13.--Precipitation rate, mass precipitation and stream hydrograph for different types of storms on the study watershed.









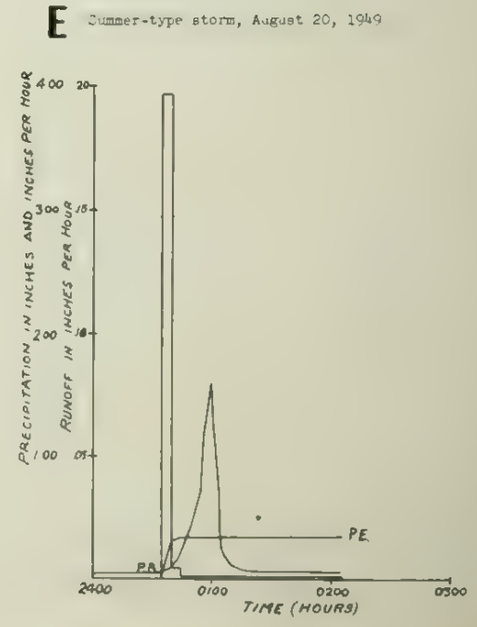


Figure 14.--Precipitation rate, mass precipitation and stream hydrograph for different types of storms on the study watershed.

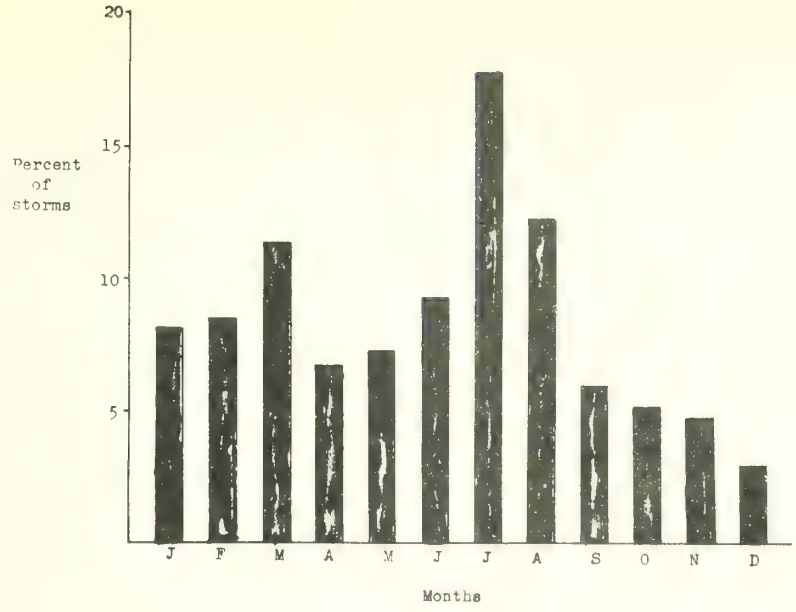


Figure 15.--Distribution chart, Little Hurricane Watershed, shows that over 39 percent of flood-producing storms occur in June, July, and August.

CHANGES IN RUNOFF CHARACTERISTICS

Probably the most important single tool of the hydrologist or watershed manager is a knowledge of the stream flow and runoff characteristics for a given drainage area. A knowledge of these characteristics guides the engineer or land manager in planning flood control measures or permits municipalities to select and manage watershed lands as well as to regulate consumption. Considerable attention has been given to the study of streamflow characteristics on large basins, particularly within the past 10 years, by the United States Department of Agriculture and the United States Corps of Engineers. Numerous investigations have been made to determine primarily gross runoff characteristics from small watersheds and plots.

It is the intent of this study to determine not only the percent of total runoff, but to evaluate any changes in surface or storm runoff in terms of flood peaks, the frequency of floods and the manner in which storm water actually runs off a small watershed. No attempt has been made, however, to study any changes in base or subsurface flow or total water yields.

Runoff Percent

One frequently used method of expressing surface runoff is runoff percent or the calculation of the percentage of total precipitation which comes off the drainage area in the form of overland flow. To evaluate the gross changes in surface runoff, an analysis of the runoff percent for the watershed in forest cover and following treatment was made.

The total storm runoff for all storms from the watershed while in forest cover (1934-1939) averaged 2.66 percent of the precipitation. Following forest cutting and mountain farming, this value increased to 4.50 percent. For summer storms only, the difference is more marked. Under forest conditions, a runoff percent of 1.53 was noted, compared with 4.79 percent following the treatment. This represents an increase of 3.26.

percent, which at first may appear rather insignificant; however, in terms of volume for a 2-inch storm as defined herein, this amounts to over 5,500 cubic feet. The following tabulation shows the increased storm runoff resulting from summer storms of 1/2 to 5 inches precipitation.

Storm precipitation (Inches)	Increased volume of surface runoff (Cubic feet)
0.5	1398
1	2756
2	5512
3	8268
4	11024
5	13780

Changes in Flood Peaks

Flood peak magnitudes and frequencies are both valuable tools used to express and evaluate the effects of various land use practices. These factors are both used frequently to aid in the determination of the economic design of engineering structures and in flood control programs.

Flood peak magnitudes.--One of the most pronounced changes in surface runoff occurring as a result of forest cutting and subsequent mountain farming is the increase in the magnitude of flood peaks. To obtain a measure of this change, a flood peak magnitude study was made. Similar studies were made on this watershed in 1949 and 1950.6/ After an examination of the previous analyses, however, it was believed that the results therefrom were not entirely satisfactory.

The first step in such a study is the collection and cataloging of storms on some rational bases. In the earlier studies a specified minimum peak was used as a basis for storm comparison. The writer believed that a more satisfactory bases for comparison was the storms themselves, i.e., a certain amount and intensity of precipitation. Consequently, for this study, storms with a maximum 30-minute rainfall intensity of over 0.90 inch per hour were arbitrarily selected.

An orientation analysis was made in which the peak discharges in cubic feet per second per square mile were plotted against the maximum 30-minute precipitation intensities by periods. Three periods were selected: 1934-1939, 1940-1945, and 1946-1951. The 1934-1939 period represents the pretreatment period in which the watershed was in forest cover; 1940-1945, the intermediate period, in which the mountain farming treatment was applied and in which the soil gradually lost its original structure, organic content, and fertility; and 1946-1951, the after period, in which the maximum effects of land use were in evidence.

From these graphs it was apparent, particularly in the pretreatment period, that intermediate and winter storms gave considerable spread to the points. A further examination of the storm data indicated that multiple

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6/ Unpublished reports, Coweeta Hydrologic Laboratory.

summer storms too were responsible for considerable dispersion of the points. An attempt was made to evaluate further the data on the basis of antecedent moisture conditions. Due to time limitations, additional analyses of antecedent moisture conditions have not been made.

Using only the selected storms, i.e., single or uniform summer storms, a new listing of storm peaks and corresponding precipitation intensities was made by periods and for maximum precipitation intensities of 15, 20, 30, and 60-minute intervals. For ease in handling, the data were grouped into 25 c.s.m. groups or classes (0-25, 26-50, etc.) and averages computed. The average c.s.m.'s for the group or class were then plotted against the class average precipitation intensities for each of the four precipitation intensity intervals for each of the three periods.

Least square linear regressions were calculated for all plottings and straight line curves fitted to the data.

The standard error of the estimate for the regressions was calculated for all four rainfall intensity intervals in the 1946-1951 period, and the 15-minute interval gave the lowest error. The time of concentration for the watershed following treatment was approximately 15 minutes; consequently, this interval was selected as best for purposes of comparison.

To show that the changes were not the result of changes in storm characteristics and precipitation patterns, the corresponding storm peaks from a control watershed were plotted against the rainfall intensities applied to watershed No. 3 for the 15-minute precipitation interval for the three periods. The resulting curves showing the relation between maximum discharge rate and precipitation intensity for both watersheds for the three periods are given in figure 16.

It is obvious from the curves for the treated watershed, that a marked increase in the magnitude of flood peaks has been effected. Similarly, the curves for the control watershed indicate that there has been no decided change in climatic conditions which might affect this increase. Consequently, the changes in flood peaks are attributed to forest cutting and subsequent land use.

The increase in flood peaks brought about by the treatment of the watershed for the maximum 15-minute period of precipitation at 2, 3, 4, and 5 inches per hour are summarized in Table 3 by actual flood peaks in c.s.m. as well as in percentage increases.

An additional study was made to show the changes in the magnitudes of flood peaks, using all storms with maximum 30-minute precipitation intensities exceeding 0.90 inch per hour. In this study the maximum flood peaks in cubic feet per second per square mile from watershed No. 3 were plotted against the maximum peaks recorded for the control watershed (No. 2) for the same storms for the 1934-1939 and 1940-1951 periods. Least square linear regressions were calculated and straight line curves fitted to the data. The results of this analysis are presented in figure 17.

The increased magnitude of flood peaks is even more marked than in the case when only unit summer storms were used. Prior to the treatment of watershed No. 3, a storm producing a flood peak of 30 c.s.m. on watershed No. 2 showed a peak of 41 c.s.m. on watershed No. 3. Similarly, a storm producing

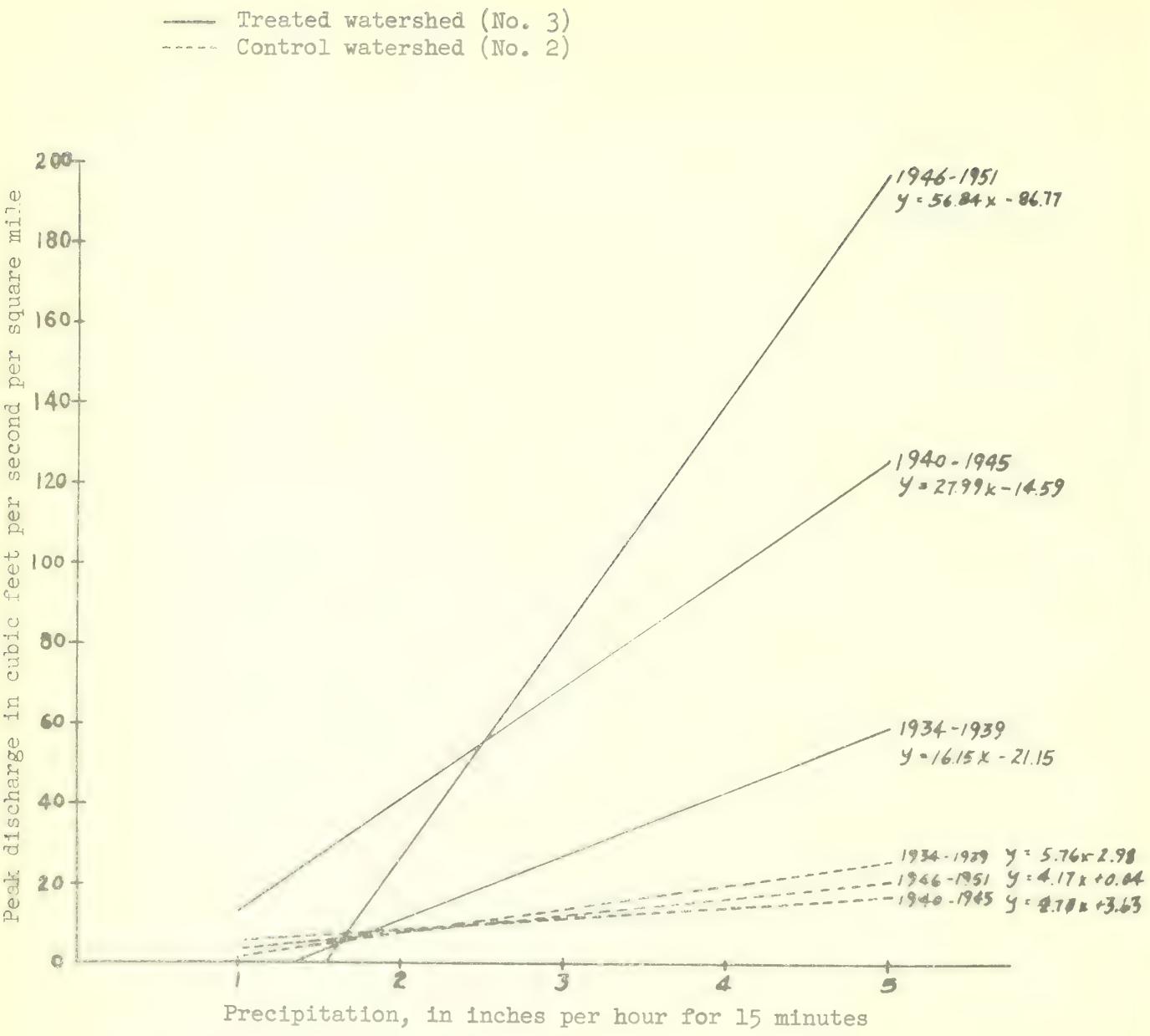

Figure 16.--The effect of forest cutting and subsequent mountain farming on maximum discharge rate, as related to precipitation intensity. Based on selected uniform summer storms having a maximum 30-minute precipitation intensity over 0.90 inches per hour.

a peak of 70 c.s.m. on watershed No. 2 produced a peak of about 85 c.s.m. for watershed No. 3. Following forest cutting and mountain farming, the peaks for watershed No. 3 corresponding to 41 and 85 c.s.m. values for the 1934-1939 period had increased to over 360 and 670 c.s.m. respectively.

In examining the individual storms and the resultant flood peaks, the highest flood peak recorded for the period that the watershed was in forest cover was 109 c.s.m. In the 11-year period following forest cutting and mountain farming 12 floods occurred which exceeded this former maximum peak. The highest peak recorded was that of July 10, 1949, which exceeded 1849 cubic feet per second per square mile. The two highest 5-minute precipitation intensities recorded during the 17 years of record, however, both occurred prior to 1940 while the watershed was forest covered.

Table 3.--Changes in flood peaks following forest cutting and mountain farming

Precipitation for 15 minutes	Peak for 1934-1939	Peak for 1940-1945	Increase over 1934-1939	Peak for 1946-1951	Increase over 1934-1939
Inches per hour	C.s.m.	C.s.m.	Percent	C.s.m.	Percent
2	11	42	382	27	245
3	27	70	260	84	311
4	43	97	226	141	328
5	59	126	213	197	334

From these analyses it is apparent that the treatment of the Little Hurricane watershed has effected striking increases in the magnitude of flood peaks.

Flood peak frequencies.--Even a cursory examination of the data reveals a marked change in the frequency of floods following forest cutting and treatment of the watershed. To get a quantitative measure of this change, a flood peak frequency study was made. The same standard used in the flood peak magnitude study, i.e., floods resulting from storms having a maximum 30-minute precipitation intensity of over 0.90 inch per hour, was used as the basis for this study, except that all storms, winter, intermediate and multiple as well as summer, were included.

The flood peaks for the watershed for the period in which the watershed was in forest cover, 1934-1939, and the treatment period, 1940-1951, were classified separately into 10 c.s.m. groups and arranged in order of magnitude. Mass totals were then calculated in order of descending magnitude. From these values occurrence percentages were computed. The mid-points of the c.s.m. classes were then plotted against their corresponding percentages on a logarithmic scale and smooth curves fitted to the data to give the frequency curves in figure 18. A logarithmic scale was selected for the ordinate in order to emphasize the maximum flood peaks, since these are the values which are of greatest importance in watershed management and flood control work as well as in engineering structures for water and erosion control.

To show that the changes are a result of the treatment rather than of climatic fluctuations during the treatment period, the same procedure was followed for the control watershed which was in forest cover for the entire period, except that 5 c.s.m. classes were used to better define a curve in graphic presentation. Figure 19 shows these resulting frequency curves.

It is apparent from figure 18 that a decided increase in flood frequencies has been effected. Assuming an average of 50 storms of flood magnitude in 10 years, 12 flood peaks over 50 c.s.m. could be expected with the watershed in forest cover. Compared with this, 25 flood peaks in excess of 50 c.s.m. should occur following forest cutting and subsequent mountain farming. On the

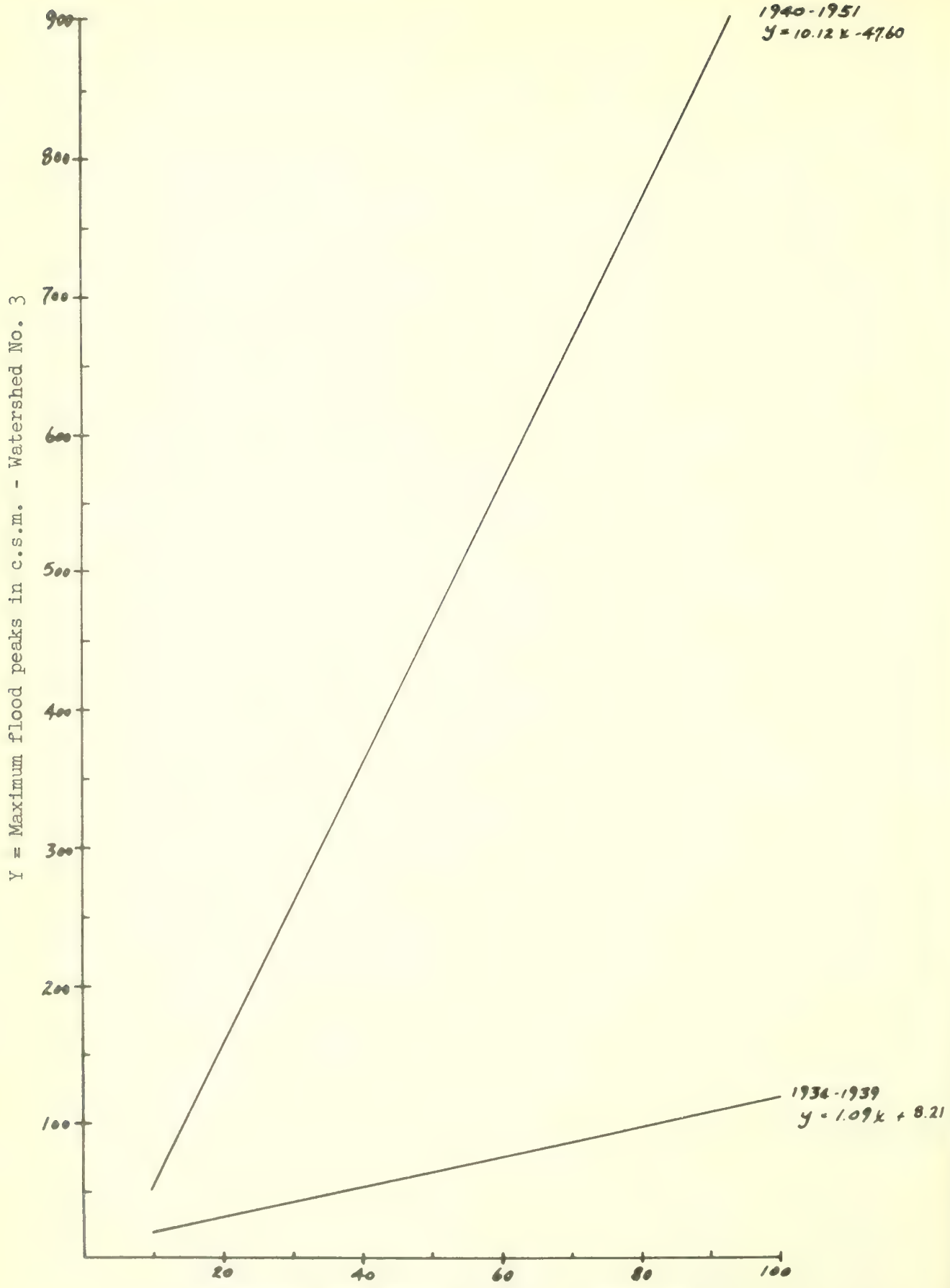

Figure 17.--Maximum flood-peak relation between control watershed No. 2 and study watershed No. 3. Based on all storms with a maximum 30-minute intensity over 0.90 inches per hour.

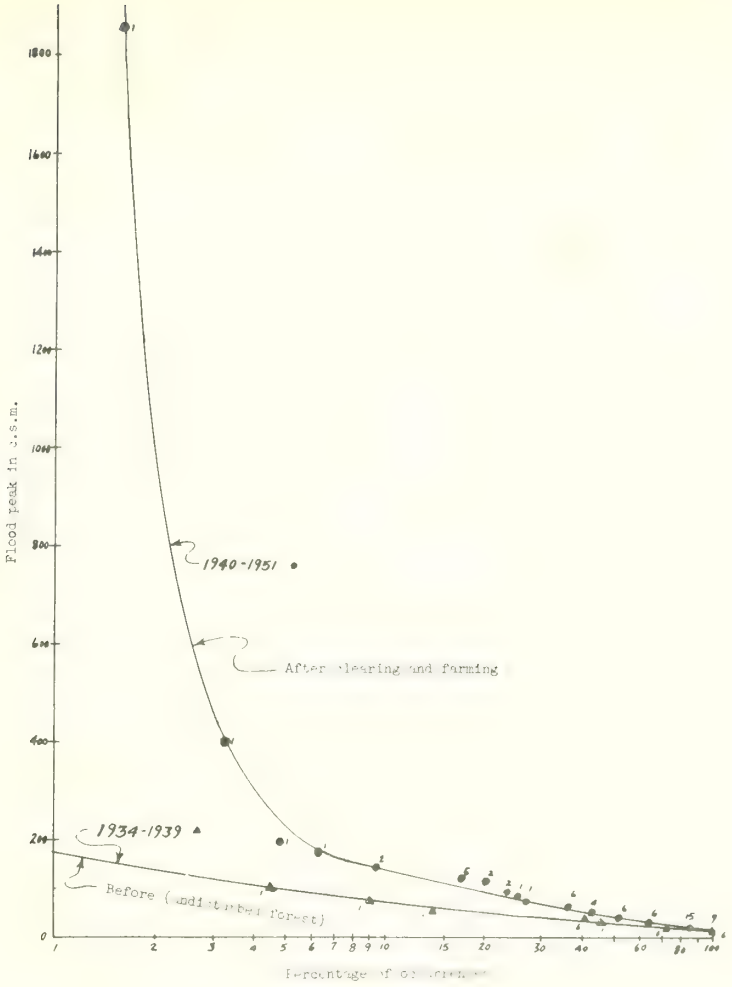

Figure 18.--Frequency of flood peaks, study watershed (No. 3).

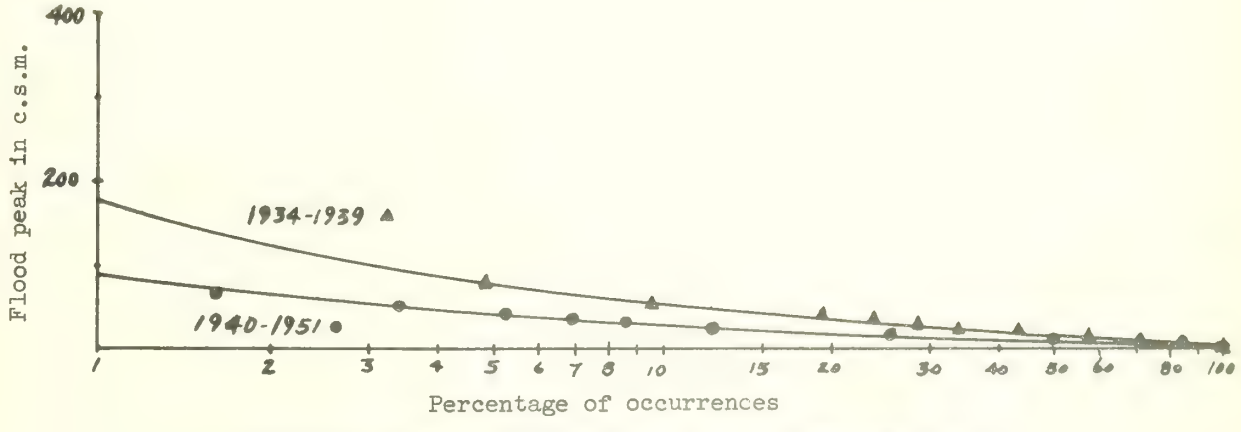

Figure 19.--Frequency of flood peaks, control watershed (No. 2).

same basis, at the 100 c.s.m. level, only 2 to 3 flood peaks from the forested watershed could be anticipated as compared with at least 10 flood peaks in excess of 100 c.s.m. from the treated watershed.

The corresponding curves for the control watershed (fig. 19) show that no great change has taken place in the precipitation pattern. Actually, the 1934-1939 period shows higher flood frequencies than the post-treatment period, indicating that possibly, had climatic conditions been even more alike for the two periods, the changes brought about on the treated watershed would have been even more marked.

Table 4 summarizes the changes in flood peaks at the 1, 2, 5, 10, 20, 50 and 80-percent levels for the Little Hurricane Watershed.

This increase in flood frequency, along with the increased magnitude, aids in explaining why channel bank vegetation is being removed and why the vegetation which starts growing on this site is washed away before it has an opportunity to become firmly established.

Table 4.--Frequency of flood peaks before and after forest cutting and subsequent mountain farming

Period	Percent of observations						
	1	2	5	10	20	50	80
	Maximum flood peak in c.s.m. exceeds....						
1934-1939	175	135	100	75	55	30	20
1940-1951	2000+	1000	230	130	100	60	30

Distribution of Storm Runoff

To show the effects of forest cutting and subsequent mountain farming on the manner in which storm runoff comes off the experimental watershed, distribution graphs were made for the two periods, 1934-1939 and 1940-1951. The method outlined by Wisler and Brater (29) was used to prepare the storm distribution graphs.

Five storms, two for the "before" period and three for the "after" period, were selected for this study on the basis of similarity in storm type and precipitation amount and intensity. The bases of the hydrographs were divided into 3-minute intervals and the total flow and the base flow were calculated for these intervals. Three-minute intervals were selected to give a total of approximately 20 equal intervals or points for subsequent graphical analysis. Storm runoff was obtained by subtracting base flow from total flow (unit hydrographs). Storm runoff percentages were then computed for each 3-minute interval. Storm data for before and after periods were averaged and these values plotted to give the final distribution graphs for the two periods which are shown in figure 20.

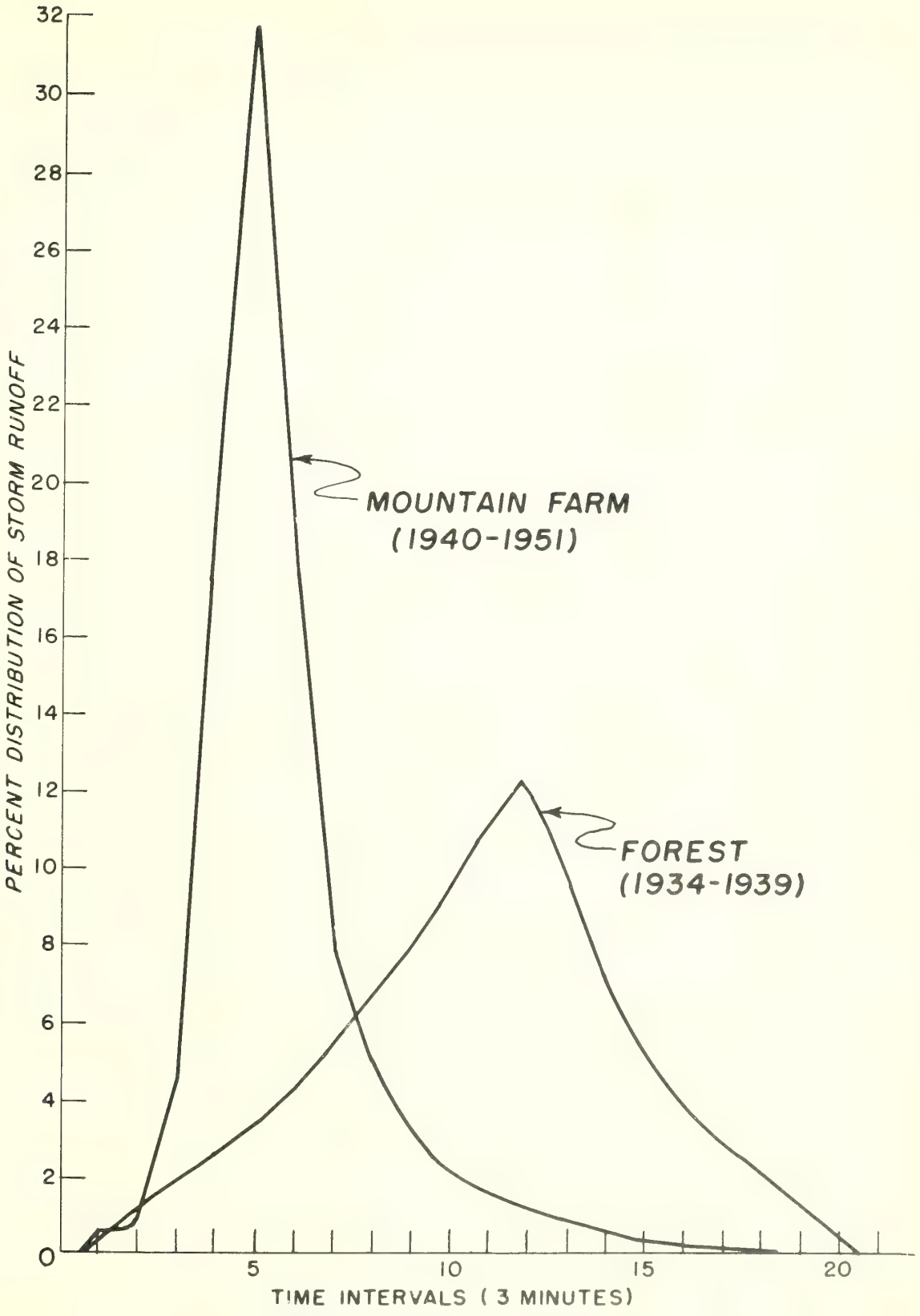

Figure 20.--Effects of forest cutting and subsequent mountain farming on the distribution of storm runoff.

To show the difference in the volume of storm runoff coming off the watershed at maximum flood stage, a time period equal to one-tenth the base of the hydrograph (3-minute interval on each side of the actual peak) was marked off on the distribution graphs and the percentages for these intervals were determined by planimeter. These results too are given in figure 20.

It is obvious from these graphs that a definite change has taken place in the distribution of the storm runoff. One notable effect is the change in the time of concentration (time that runoff began to the time of the maximum peak) for the watershed. While the watershed was in forest cover, the peak occurred approximately 35 minutes from the time storm runoff first began. Following forest cutting and mountain farming, the peak occurred on the average of 15 minutes after runoff began. In a few cases, with short intense summer storms, the time from the start of runoff to the peak was observed to be as little as 10 minutes.

It is apparent, too, that the peak percentage itself was more than doubled as a result of the treatment. While in forest cover, the maximum value was approximately 12 percent; following cutting and treatment, this value jumped to approximately 32 percent. Apparent too, is the change to an almost needle-shaped storm hydrograph.

Significant also is the change in the peak percentage based on the maximum discharge for a time period equal to one-tenth the base of the storm hydrograph. For the "before" period, this amounted to 24 percent of the total storm runoff. As a result of treatment, the peak percentage increased to 49 percent.

SUMMARY

For many years it has been a common practice in the Southern Appalachians to clear off the native forest cover on steep slopes and then to attempt to farm the cut-over area. In this study a determination of the effects of this use of land on some of the biologic, edaphic and surface runoff characteristics of a 23-acre watershed was made with the following results.

Biologic Changes

By clear cutting the forest cover and applying different land use practices to the watershed a marked change in the vegetation was produced. Nearly half of the watershed, approximately 10 acres, was permitted to grow back into natural forest cover. Eleven years after cutting and negligible use by cattle, the dominant sprouts and seedling trees are approximately 3 to 3-1/2 inches in diameter at breast height and 12 to 15 feet in height. By examining adjacent uncut areas and timber cruise data, it was found that there is little change in species composition in this coppice forest area except for the presence of wild plum, hawthorne and staghorn sumac. These invading species will probably disappear within a few years following complete canopy closure.

Shrubby and herbaceous cover in the coppice forest area is very sparse except along the ridges and in a few openings. Many species

associated with forest openings were observed, although most of these will probably disappear within a few years. In most of the adjoining forest area there is a moderate understory of mountain laurel and rhododendron. It is apparently much slower in becoming re-established than many other species since it is fairly common only near the ridges in the coppice forest area.

In the two pasture areas as well as in the abandoned cornfield, the most marked changes are those in vegetation density and in species composition of the shrubby and herbaceous cover. On all three areas vegetation density is low, particularly in the lower pasture. Changes in species composition were marked by the appearance of such more or less noxious or unpalatable species as mullein, yarrow, Canada thistle, smartweed, nettle and purslane--all frequently associated with land abuse.

In the control plots, established in the cornfield at the time it was abandoned in 1949, the ground cover is nearly complete after only two years. The most abundant species in these two plots are blackberry and wild strawberry. It is obvious in both plots that tree species will soon take over. Numerous stems in both plots exceed 6 feet in height.

In the absence of forest vegetation, stream temperatures increased to the point where they are critical or above the maximum limits for trout. Similarly, stream turbidities were increased by approximtely three times, and siltation or sedimentation increased tremendously.

Edaphic Changes

The results of an infiltration study made in 1949 showed marked differences in the infiltration rates of the portions of the watershed used in different ways. In all the forested plots sampled on the Coweeta area, including the coppice forest portion of the Little Hurricane Watershed, the average infiltration rate invariably exceeded 6 inches per hour. The values noted for the cornfield, upper pasture, and lower pasture respectively in 1949 were 4.00, 3.00 and 0.56 inches per hour. Since many of the storms on the Coweeta area show precipitation intensities in excess of 0.56 inches per hour, high surface runoff rates would be anticipated from the lower pasture. Similar infiltration tests made on the abandoned cornfield immediately before and following grazing in 1950 indicated that even short periods of grazing caused sharp decreases in the infiltration rate.

As indicated by samples collected from an adjacent watershed, the permeability of undisturbed forest soil averaged well over 100 inches per hour in the 0-3 inch layer and over 60 inches per hour in the 3-6 inch zone. Tests on soils collected from the mountain farm area showed minimum values in the lower pasture where the average rates were 6.6 and 2.7 inches per hour for the 0-3 and 3-6 inch layers respectively.

The percent of water-stable aggregates similarly were much higher in the forested areas. In the undisturbed forest the percentages of water stable aggregates over 4 mm. in size in the surface and subsurface layers were 85.5 and 73.8 respectively, compared with percentages of 46.2 and 40.1 in the control plots in the abandoned cornfield. The soil dispersion re-

sulting from the decrease in aggregation is undoubtedly responsible for increases in soil losses from the watershed and indirectly for the increases in surface runoff. An analysis of the aggregation of the fine earth material indicated similar results.

Differences in organic matter content, volume weight, and porosity are also evident. The effect of former cultivation in the abandoned cornfield is evidenced in that the organic matter content of both surface and subsurface layers are nearly the same. In the control plots in the abandoned cornfield the organic content of the subsurface layer is approximately the same as in the cornfield itself. However, the 2 years protection offered the control plots appears to have been sufficient to increase the organic matter content materially in the surface layer. The lowest organic matter content in both layers is noted for the lower pasture. Apparently, grazing has brought about soil compaction and thus inhibited the incorporation of litter and humus. It is probable, too, that earlier cultivation of this area may have caused soil changes in the lower pasture. The coppice forest area showed the highest content of organic matter in both layers. This is probably the result of an accumulation of litter from slash and a heavy herbaceous cover following clear cutting and the decaying of root systems from the trees formerly occupying the area.

The greatest differences in volume weight in both layers were found between the coppice forest and the lower pasture, indicating a close relationship between organic matter content and volume weight. In the surface layer, volume weight values range from 0.82 to 1.11. In the subsurface layer all values are very nearly the same except in the lower pasture where volume weight was 1.28, again showing the effects of trampling. These values, as well as those noted for organic matter content, suggest that the most marked changes in the physical characteristics of the soil occur in the 0-3 inch layer.

In porosity values, a slight decrease in total and noncapillary porosity and an increase in capillary porosity, in comparison with undisturbed forest conditions, is indicated. In noncapillary porosity a decrease of approximately 6 percent by volume is shown. According to many writers, noncapillary porosity determines permeability. From the results of these determinations, small changes in the large pore volume, then, may effect marked changes in permeability rates.

One of the greatest changes in the soil as a consequence of the treatment is in soil losses from the watershed. During the calibration period, 1934-1939, and until August, 1941, the average soil losses amounted to about 154 pounds per acre per year. Following the cutting of the forest and the application of mountain farming practices, the average soil losses increased to well over a ton per acre per year. A small portion of this increase might perhaps be attributed to a change in the method of collecting soil losses. However, virtually all the increase should be assigned to the treatment of the watershed.

Cultivation alone appears to be responsible for marked increases in soil losses. These losses increased sharply for a 2-year period following the cutting of the forest cover in which the cornfield was cultivated and the pasture areas were grazed. During 1944 and 1945 the cornfield was protected and permitted to lie idle while the pastures were being grazed. During

this period, soil losses dropped noticeably. Following this, the cornfield was again cultivated for 4 years and the soil losses mounted to a high in 1949 of over 2-1/2 tons per acre per year. In 1950 and 1951 cultivation was discontinued and the abandoned cornfield was grazed along with the two pasture areas, and again soil losses declined.

Runoff Changes

A study made on the Little Hurricane Watershed indicated an average runoff percent of 2.66 for all storms with a maximum 30-minute precipitation intensity over 0.90 inches per hour for the period in which the area was in forest cover. Following forest cutting and mountain farming, this was increased to 4.50 percent. Summer storms alone gave percentages of 1.53 and 4.79 for the before and after periods, respectively.

A very significant change in the magnitude of flood peaks occurred as a result of the land use treatment applied. Unit summer storms yielding precipitation at the rate of 3 inches per hour for 15 minutes, for example, showed an increase in the resulting maximum flood peak from 27 to 84 cubic feet per second per square mile. At the rate of 5 inches per hour for 15 minutes the increase theoretically would be from 59 c.s.m. to approximately 335 c.s.m.

A study of flood peak frequencies for the watershed indicated similar marked changes. During the period of standarization, only three floods occurred with maximum peaks over 50 c.s.m., while following treatment 25 floods with maximum peaks in excess of 50 c.s.m. were noted. A similar analysis of data from a control watershed actually indicated lower frequency values for the later period.

One of the most significant changes in surface runoff brought about by forest cutting and subsequent mountain farming is the manner in which the runoff water comes off the watershed. Runoff distribution graphs comparing the before and after periods show that the peak runoff occurs about 15 minutes after the beginning of a storm since the area has been treated. Before clearing, the peak runoff did not occur until about 35 minutes after the beginning of a storm. For both periods the duration of runoff was approximately 60 minutes. Prior to treatment approximately 12.5 percent of the storm flow came off the watershed during the peak 3-minute interval. Following treatment, this value jumped to nearly 32 percent.

PRACTICAL IMPLICATIONS FOR LAND USE

As a result of increasing population and economic pressures, thousands of acres of steep forest land within the Southern Appalachian region have been cleared for use as pasture or cropland. The advisability of this practice has been extremely questionable from an agronomic and, particularly, from a hydrologic standpoint. The results of this study show that forest cutting and the application of average to poor farming practices have a very deleterious effect upon the physical properties of the surface soil and increase surface runoff during storms.

Within a short period of time after cultivation is begun, the organic constituent and natural structure of the former forest soil begin to break down, leading to soil dispersion and resultant accelerated erosion. When row crops are cultivated on steep land, the exposed topsoil washes away increasingly with each year and fertility declines until, after a period of a few years, yields have decreased to the point where the operation is no longer profitable.

Since the farmer invested a great deal of labor in the original clearing, he frequently decides to convert the worn-out area to pasture instead of allowing it to return to forest cover.

All too frequently the land now becomes overgrazed, which results in rapid compaction of the already eroded soil due to trampling by the cattle. Infiltration and permeability rates quickly decline, and the soil loses its capacity for water storage. The cumulative effect of these abuses is to increase the volume of surface runoff and to multiply the frequency and magnitude of floods which would have occurred under natural forest conditions.

At first glance, it might appear that the injury is confined to an already worn-out area and thus is of minor consequence. However, once these floods begin to occur in increasing number and magnitude, it becomes clear that the damage is much more extensive and much more serious.

Such flood source areas produce erosion on lower lands which normally would not be subject to serious soil washing. Within the past 10 years many farmers in this region, who depended on the cultivation of row and truck crops in the first bottom lands along the streams for their greatest source of income, have been forced to convert these areas to permanent pasture which can withstand increased flooding.

Results such as these could probably be expected from average to poor farming practices in other areas with similar topography and soils. It might be suggested that better farming methods could alleviate the situation. Corn might be rotated with clover and small grains, and the amount of fertilizer used could be increased to advantage. Less damage from trampling would occur if fences were built and fewer cattle permitted to graze. However, all these improved practices are difficult and expensive on such steep land.

When stream conditions in undisturbed forests are observed, one is convinced that good forests, good soils and good water go hand in hand. Soil conditions under undisturbed forest encourage storage of water and make possible the control of erosion. It is reasonable to believe that through the ages there has developed harmonious adjustment of vegetation, soil and water. This natural adjustment, however, appears to be in delicate balance. It is impossible to disturb the forest without distrubing this equilibrium.

It is oviously impractical, however, to leave all land in forest no matter how excellent the supply of water thus assured would be. Land must be used, but must also be carefully managed in order to husband its potentialities for human satisfaction. As we come to understand all of the physical forces which must be kept in balance, we will be better able to develop land management practices which will permit us to utilize all resources without exploiting any one at the expense of another.

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Managing Shortleaf Pine in Littleleaf Disease Areas

by

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COVER PHOTO:

Healthy tree on the right,
littleleaf trees at left
and center.

MANAGING SHORTLEAF PINE IN LITTLELEAF DISEASE AREAS[1/]

by

W. A. Campbell, Otis L. Copeland, Jr., and George H. Hepting[2/]

INTRODUCTION

Investigations on the cause of the littleleaf disease of shortleaf and loblolly pines, and on possible remedial measures, have been in progress for approximately 12 years. In 1945, the results of investigations up to that time were summarized in a U. S. Department of Agriculture Circular (5). Since then numerous publications have appeared on the cause, soil relationships, and related phases of the study. Recommendations for management of shortleaf pine in areas where the disease is common are summarized here for use by foresters and landowners.

DISTRIBUTION AND ECONOMIC IMPORTANCE OF LITTLELEAF

Littleleaf occurs in varying amounts in seven southeastern States (fig. 1). The littleleaf belt extending from Virginia to Mississippi embraces approximately 30 million acres, of which over half is in forests. The darker shaded portions of the map, which indicate areas of abundant littleleaf, cover about 5 million acres of forest land.

Even in areas of greatest abundance, littleleaf is not uniformly distributed throughout shortleaf pine stands. Age of stand, soil conditions, and degree of erosion are important factors in the distribution of the disease. In the Piedmont and other physiographic regions where littleleaf occurs, limited areas of severe littleleaf may be found in close proximity to healthy stands. This spotty occurrence of littleleaf in many areas and relative lack of the disease in nearby stands makes an understanding of its cause and soil relationships rather important.

1/ The littleleaf disease research program has been carried on mainly in cooperation with the Southeastern Forest Experiment Station, U. S. Forest Service, and the School of Forestry of the University of Georgia.

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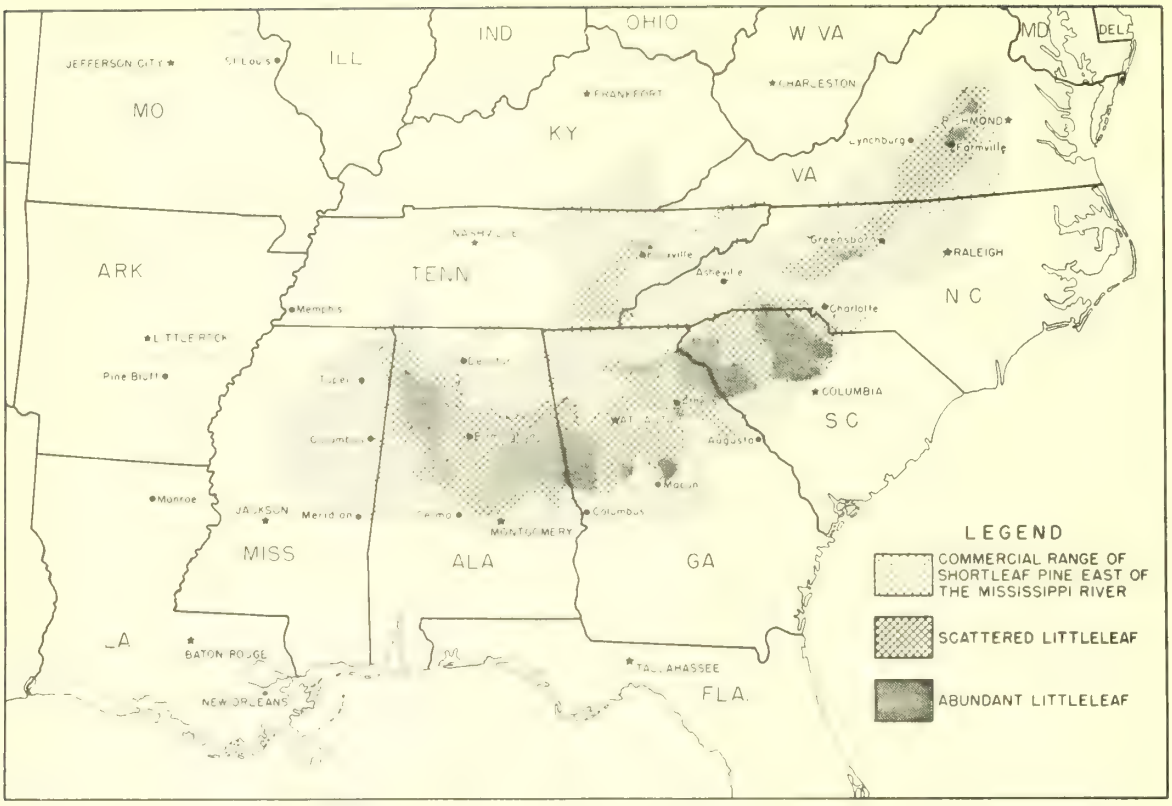


Figure 1.--Known distribution of littleleaf disease of shortleaf and loblolly pines.

No discussion of littleleaf would be complete without some estimate of the losses caused by it on approximately 15 million acres of forest land within the littleleaf belt. Fortunately, valid estimates on the losses from littleleaf in Piedmont South Carolina exist from a forest survey made in 1947 (4). At that time 118 million board feet of shortleaf pine were recently dead or in the advanced stages of the disease. This meant that about 39 million board feet would die each year, since trees in the advanced stages have a life expectancy of less than 3 years. The data for South Carolina were computed independently for areas of scattered and abundant littleleaf, thus making possible estimates of mortality in the other six States. These estimates are given in table 1. Due allowances have been made for differences in forest acreage and other factors such as relative age of stands. Estimates are also included for loblolly pine mortality in States in which an appreciable volume of this species is affected by littleleaf.

Not all expected mortality can be considered as loss, since much salvage cutting of diseased trees prior to death is done in littleleaf-affected areas. Although no allowance for trees salvaged was made in the loss estimates, the salvage is probably more than counterbalanced by loss in increment due to the understocking of littleleaf-ravaged stands, and the growth loss in diseased trees prior to death. As soon as littleleaf symptoms appear, radial growth practically stops, and although diseased trees may live for 10 or more years from the onset of symptoms, they do not increase materially in size. Another type of indirect loss arises from the accelerated conversion of pine stands to hardwoods, which takes place as pines are killed by littleleaf.

Besides the loss in trees of saw-timber size in South Carolina, 46,000 cords of wood in the 6 to 8-inch class are killed annually by littleleaf. This would conservatively place the annual mortality in trees of this size over the entire littleleaf belt at more than 250,000 cords.

Table 1.--Estimated annual mortality from littleleaf, based on 1947 field data

State	Shortleaf pine	Loblolly pine
	M bd. ft.	M bd. ft.
Alabama	69,000	13,000
Georgia	55,000	5,000
Mississippi	1,400	0
North Carolina	9,800	0
South Carolina	38,000	3,800
Tennessee	5,000	0
Virginia	15,000	0
Total	193,200	21,800

THE CAUSE OF LITTLELEAF

The symptoms of littleleaf develop largely from the gradual killing of the fine roots by the parasitic fungus Phytophthora cinnamomi and probably to a lesser extent from other cuases. Experimental inoculations have demonstrated that new root ends and very young roots are most susceptible to infection. The gradual loss of the fine absorbing roots interferes especially with the absorption of nitrogen, leading to a slow cessation of growth and yellowing of the foliage, followed by premature death.

Phytophthora cinnamomi is widely distributed in the soils of the Southeast, occurring in the coastal plain and other areas where littleleaf is absent. Its ability to attack roots severely depends to a great extent on soil type and condition. Experimental work has shown that root infection is very limited in sandy soils, more common in loams, and severe in silts and clays. Since the fungus requires abundant moisture to produce the swarm spores that cause infection, root damage increases as the subsoils become more poorly drained. The relationship between soil internal drainage and root infection helps to explain why the disease is confined to the heavier soils of the Piedmont and related areas.

Recognition of the role played by a parasitic root fungus and of its dependence upon certain soil conditions to cause severe root mortality is important in the development of plans for the management of littleleaf areas. The disease does not normally spread from diseased trees to healthy trees through transfer of inoculum. The fungus is already present in most southeastern pine soils and the development of littleleaf is conditioned almost entirely by soil factors which cannot be changed materially except over long periods of time.

SOIL SERIES AND SOIL CONDITIONS IN RELATION TO LITTLELEAF

Early progress reports on the investigation of littleleaf suggested that severe symptoms were associated with frequent burning, low site index, soil erosion, and steep slopes. In 1948, on the Calhoun Experimental Forest near Union, South Carolina, on various soil associations littleleaf severity was found to increase as internal drainage of the soil profiles became poorer (2).

In order to explain these apparent relationships, a more extensive soils-littleleaf study was begun in 1949 throughout the littleleaf region of the southern Piedmont. Forest vegetation, soil characteristics, and disease severity were studied in the search for factors associated with the disease.

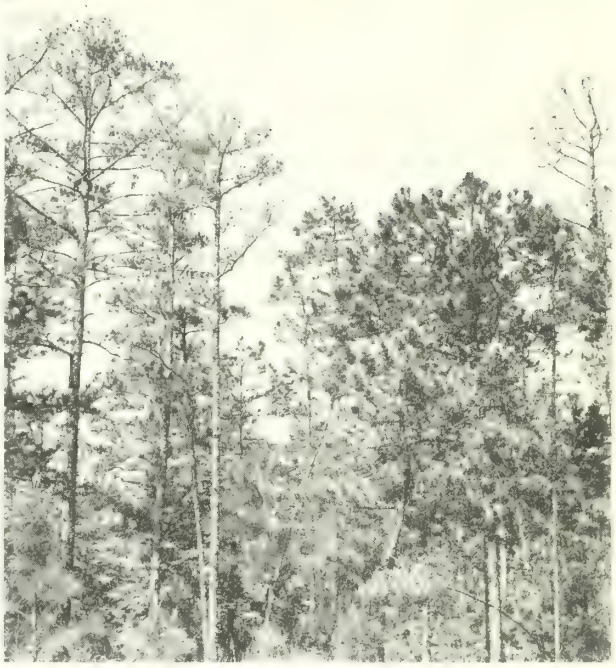
The amount of littleleaf varies greatly on different soils, and although disease severity may vary from site to site on any one particular soil, the average amount of littleleaf follows a fairly regular relationship to the internal drainage condition of a particular soil series (table 2). Internal drainage is defined as "that quality of a soil that permits the downward flow of excess water through it" (1). Soil texture, structure, porosity, height of water table and other factors influence it. Thus, soils with poor internal drainage are usually more nearly saturated and reciprocally less well-aerated for long periods of time and this leads to the development of less extensive pine root systems and favors infections by the root fungus Phytophthora cinnamomi.

Table 2.--A comparison of littleleaf incidence by Piedmont soil groups according to their internal drainage

Soil series group	Plots	Littleleaf trees (weighted mean)	Internal drainage
	Number	Percent	
Durham, Alamance, Cecil, Georgeville, Davidson, Lockhart, Lloyd, Nason	66	3.9	Excellent to good
Louisa, Madison, Appling, Helena	39	12.1	Good to poor
Cataula, Mecklenburg, Orange, Vance, Tatum, Herndon, Manteo, Wilkes	53	25.5	Generally poor

Two shortleaf pine stands, one healthy and the other severely diseased, on two different soils are illustrated in figure 2. The healthy stand is located on a well-developed Cecil sandy loam with medium to rapid internal drainage. At corresponding depths the transmission rates of water (measured as the flow of water through saturated cores) in the Cecil soil range from 10 to 20 times greater than in the shallow, eroded Vance sandy loam with slow internal drainage which supports the diseased stand. Greater porosity in the Cecil profile is apparent and contributes to better drainage.

According to the position of these two soils in table 2, it is apparent that the Cecil soil would normally support healthy or only light littleleaf stands, while moderate



CECIL *SANDY LOAM*

DEPTH INCHES	TRANSMISSION RATE INCHES PER HOUR	PORE SPACE PERCENT
0 – 2	10.90	59.7
2 – 4	1.62	43.8
4 – 6	0.64	36.7
6 – 8	0.79	38.6
8 – 10	0.40	30.1
10 – 12	0.65	26.8
12 – 14	0.34	14.1
14 – 16	0.18	10.6
16 – 18	0.10	5.7
18 – 20	0.15	9.1
20 – 22	0.10	12.0
22 – 24	0.05	11.2
24 – 26	0.10	7.7
26 – 28	0.04	6.8
28 – 30	0.03	6.9

30+ DISINTEGRATED ROCK

VANCE *SANDY LOAM*

DEPTH INCHES	TRANSMISSION RATE INCHES PER HOUR	PORE SPACE PERCENT
0 – 2	0.94	33.2
2 – 4	0.10	12.2
4 – 6	0.03	9.9
6 – 8	0.05	7.4
8 – 10	0.02	8.1
10 – 12	0.01	8.9
12 – 14	0.01	6.6
14 – 16	0.01	9.7

16+ DISINTEGRATED ROCK

Figure 2.--A healthy shortleaf pine stand on a Cecil sandy loam on left; a stand with littleleaf on a Vance sandy loam on right.

to severe littleleaf may be expected in stands occurring on the Vance soil. Thus table 2 affords a means of approximating expected littleleaf severity on different soil series.

More than thirty soil, vegetation, or fungus factors have been studied in relationship to littleleaf. Only two soil features, internal drainage and degree of soil erosion, are statistically significantly correlated with littleleaf severity. These two factors provide the basis for the development of a guide for estimating the littleleaf hazard for any site.

PREDICTING THE LITTLELEAF HAZARD FOR DIFFERENT SITES

An urgent need exists for a practical field guide for predicting the littleleaf hazard on different sites throughout the littleleaf region. Such a guide must necessarily be usable by foresters in the field without requiring detailed laboratory analyses or measurements.

Since a significant relationship exists between groups of soils and littleleaf severity, soil units such as series or types might be used as a guide in determining the probable disease hazard (see table 2) provided proper classification of the soil unit is made. However, in old agricultural areas, this method of estimating disease hazard could only, at best, result in predictions of a general nature because diverse farming practices have produced alterations in the original soils which may not be reflected by the mere classification of the soil as to its proper series. Therefore, a more precise rating guide is needed.

A simplified rating scale, of a preliminary nature, developed from field notes of an extensive soils-littleleaf survey is presented in figure 3, and is based upon two soil characteristics, internal drainage and soil erosion. The degree of soil erosion can be classified fairly readily; however, the accurate classification of internal drainage is difficult and requires considerable training and experience. Therefore, erosion is used in the rating scale, but three more easily evaluated characteristics--subsoil consistence, depth to zone of greatly reduced permeability, and subsoil mottling--are substituted for internal drainage. These three substituted characteristics adequately characterize internal drainage for the purpose of this rating scale.

A site expected to remain disease-free is assigned a total of 100 points. This is broken down so that 40 points are allocated to the erosion factor and 60 points to the internal drainage factor. The further division of the 60 points between the three soil characteristics used in lieu of internal drainage is shown in figure 3. It is necessary to understand the terms used in the rating scale before any attempt is made to use it.

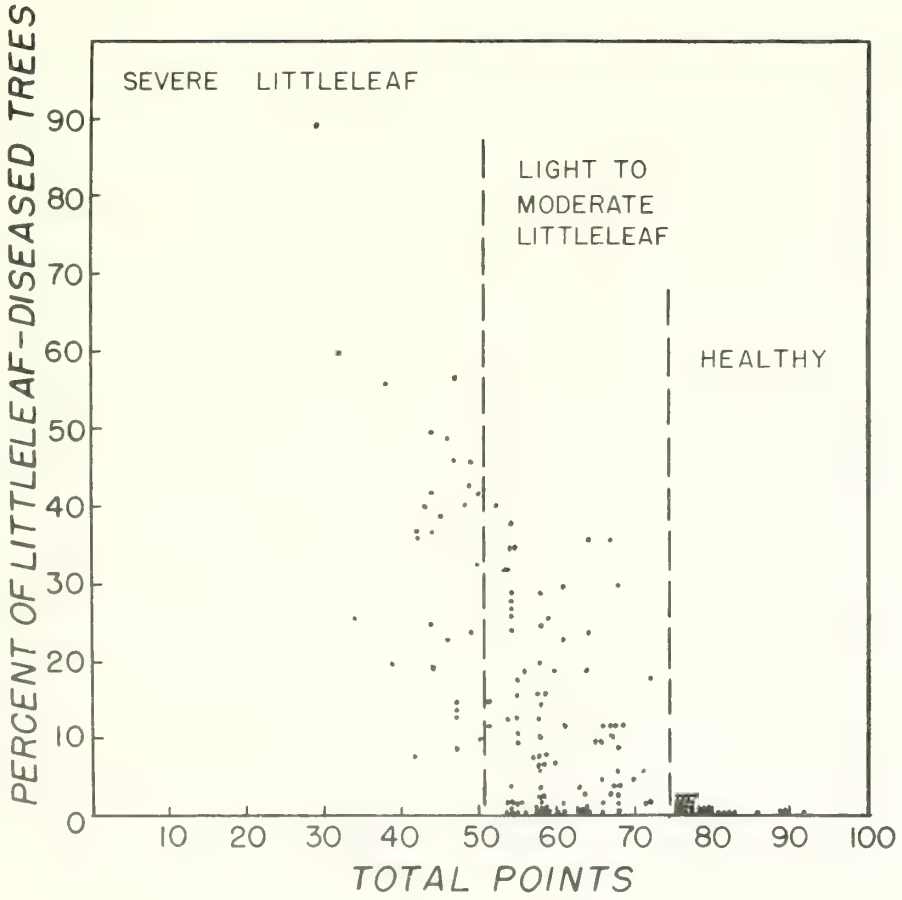
The term erosion as used in this discussion denotes accelerated water erosion and the classes used are essentially those recognized by the U. S. Division of Soil Survey (1).

Slight erosion.--The thickness and character of the A horizon has not been altered to an appreciable extent. Not more than 25 percent of the original A horizon has been removed.

Moderate erosion.--The soil has been eroded to the extent that ordinary tillage implements reach through the remaining A horizon. From 25 to 75 percent of the original A horizon may have been lost. Shallow gullies may be present.

Severe erosion.--All or practically all of the original A, and commonly part of the B, horizon have been lost. Shallow gullies are common.

Rough gullied land.--The land presents an intricate pattern of moderately deep or deep gullies. Soil profiles have been destroyed except in small areas between gullies.



SOIL CHARACTERISTICS AND CLASS	POINTS
EROSION	
Slight	40
Moderate	30
Severe	20
Rough gullied	10
SUBSOIL CONSISTENCE	
Very friable	32
Friable	24
Firm (slightly plastic when wet)	16
Very firm (plastic when wet)	8
Extremely firm (very plastic when wet)	0
DEPTH TO ZONE OF GREATLY REDUCED PERMEABILITY	
24 - 36"	15
18 - 23"	12
12 - 17"	9
6 - 11"	6
0 - 6"	3
SUBSOIL MOTTLING	
None	13
Slight	9
Moderate	5
Strong	1

Figure 3.--A soil rating scale for estimating the littleleaf hazard of a site, in which the higher the index the lower the littleleaf hazard. By the use of four soil factors, the 158 plots in the South Carolina survey are classified in the scatter diagram.

Soil consistence is that quality of soil material which is expressed by resistance to deformation. As used in this discussion, subsoil consistence is determined when the moisture content of the subsoil is approximately midway between air dry and field capacity. To evaluate consistence, select and attempt to crush in the hand a mass of soil that feels slightly moist. Customarily, descriptions of consistence refer to that of soil from undisturbed horizons. Five recognized consistence classes for moist soil are used in the littleleaf prediction rating scale (1). They are defined below.

Very friable.--Soil material crushes under very gentle pressure but coheres when pressed together.

Friable.--Soil material crushes easily under gentle to moderate pressure between thumb and forefinger, and coheres when pressed together.

Firm.--Soil material crushes under moderate pressure between thumb and forefinger but resistance to pressure is distinctly noticeable. Slightly plastic when wet.

Very firm.--Soil material crushes under strong pressure; barely crushable between thumb and forefinger. Plastic when wet.

Extremely firm.--Soil material crushes only under very strong pressure; cannot be crushed between thumb and forefinger and must be broken apart bit by bit. Very plastic when wet.

The depth to the zone of greatly reduced permeability is determined from soil pits dug by the observer and the accuracy of this determination depends upon his judgment and experience. Certain conditions such as denseness of soil layers, resistance encountered in digging, texture of soil layers, absence of cracks and large pores, and others, aid in locating this zone of reduced permeability. Usually this zone occurs near the top of or within the B horizon (1 to 3 feet), and when it is located the observer simply measures the depth to it from the soil surface.

Mottling in a soil is a splotching of a uniform color with spots of other colors. It is described by the prominence, abundance, and size of individual mottles. Within the littleleaf region, the mottling, mainly grays and browns, in soil is evidence of water saturation. It indicates impeded drainage and is usually restricted to the subsoil. Four relative classes of mottling are included in the rating scale. No great difficulty should be experienced in evaluating this factor according to the classes listed.

There are several tools available for use in examining soils--the conventional soil auger, the post-hole auger which is larger, a spade, mattock, and the common post-hole digger. The common post-hole digger is preferred because it does not grind, pulverize, or mix the soil as much as the augers. This is especially desirable for determining consistence and mottling.

As a test of its usefulness, the rating scale was applied to the 158 plots of the South Carolina soils-littleleaf survey. The plots fall into three classes: healthy sites having a rating of 75 or more points; light to moderate littleleaf hazard sites having 51 to 74 points inclusive, and severe littleleaf hazard sites having less than 51 points. The classification of the survey plots by the use of the rating scale plotted against the actual percent of littleleaf trees is shown in the scatter diagram of figure 3. The results compare favorably with the actual field classification. The healthy plots that occur in the light to moderate littleleaf group in the rating scale average 8 years younger than the healthy group and probably represent stands approaching the threshold of disease expression.

The mechanics of rating sites can be illustrated by rating the two sites in figure 2. The Cecil soil is slightly eroded, subsoil consistence is friable, depth to zone of greatly reduced permeability is 16 inches, and the subsoil is free of mottling. The Vance soil is severely eroded, subsoil consistence is very firm, depth to

zone of greatly reduced permeability is 4 inches, and the subsoil is moderately mottled. Referring to the rating scale (fig. 3), the Cecil soil has a rating of 86 points, which places it in the healthy group. The Vance soil has a rating of 36 points, which places it in the severe littleleaf group. The photographs corroborate these ratings.

SUGGESTED MANAGEMENT PRACTICES IN RESPECT TO STAND AND SITE CONDITIONS

An analysis of the shortleaf pine stands within the littleleaf belt and associated potential pine sites discloses four situations, each requiring a different approach to the management problem. These are discussed as follows:

Stands in which Littleleaf is Present

Although littleleaf may develop in stands as young as 20 years of age, the majority of those becoming diseased show first symptoms between 30 and 50 years of age. In general, the earlier symptoms appear, the more severe the resulting effect on the stand. Obviously, greater loss will result in those stands showing disease at an early age, because most of the diseased trees that should be salvaged will be too small to market except as pulpwood. Stands becoming diseased at a later date often produce a considerable volume of saw timber.

The first problem in dealing with littleleaf stands is that of properly spacing cuttings to minimize the loss of merchantable timber. Suggested cutting cycles are based on the amount of disease in the stand and the known rate of deterioration of affected trees. Elmer Roth, in a study now in progress, has analyzed the data on the dominant and codominant trees from 31 permanent sample plots covering the 10 years between 1941 and 1951. On the light littleleaf plots, in addition to the mortality among the scattered littleleaf trees that were present when the plots were established in 1941, 34 percent of the originally healthy trees showed symptoms in 1951 and 4 percent had died. On the moderate littleleaf plots, in addition to the mortality among trees originally diseased in 1941, 51 percent of the healthy trees had developed symptoms by 1951 and 8 percent had died. On the severe littleleaf areas 67 percent of the healthy trees became diseased in 10 years and 27 percent died. Therefore, on severe littleleaf areas, the expected mortality among healthy trees plus the loss of trees already diseased would lead to serious stand depletion over a relatively short period.

Hepting (3) formulated the following cutting rules for lightly, moderately, and severely diseased stands, assuming that the stands in question are relatively accessible and that littleleaf trees live for an average of 7 years from the onset of symptoms and those in advanced stages less than 3 years:

(1) Where only an occasional shortleaf pine shows littleleaf, cuts can be light and spaced at least 10 years apart.

(2) When between 10 and 25 percent of the trees show unmistakable littleleaf, cut on at least a 7-year cutting cycle, cutting all diseased or suspected trees at each cut.

(3) Where more than 25 percent of the trees show littleleaf, cut all shortleaf pine as soon as practicable from the standpoint of merchantability, since such stands are likely to deteriorate very rapidly once one-fourth of the trees are obviously diseased.

With the harvesting of present littleleaf stands, the question arises as to future prospects for shortleaf pine on the same sites. Because the disease is associated with soil conditions that cannot be greatly changed except over long periods of time, succeeding crops of shortleaf pine may be expected to fail at the same or even at an earlier age. However, since many of these sites provide satisfactory yields of pulpwood, they may be managed on short rotations without undue interference from this disease.

Soil improvement has been suggested as one means of combating littleleaf. This can be accomplished by encouraging hardwoods, especially such species as dogwood, yellow-poplar, and hickory, which are known to improve soils. Hardwoods are more effective than pine in building humus. Metz (7) lists the common Piedmont hardwoods by their yield of nitrogen, calcium, and magnesium from the foliage. Practically all hardwoods return more nitrogen, calcium, and other elements to the soil than pine, and the eventual change to a greater proportion of broad-leaved species in littleleaf areas may serve to reduce the incidence of disease, not only by decreasing the number of trees that are susceptible to attack, but also by providing more favorable growth conditions for the existing pine. However, any effect on pine would be on future stands, and those older individuals now occupying the site could scarcely be expected to benefit immediately by conversion to hardwoods.

Loblolly pine on severe littleleaf sites is approximately one-third as susceptible as shortleaf and should, therefore, be favored wherever possible. Also, other pines, such as Virginia, pitch or longleaf should be encouraged, where feasible, in order to build up the percentage of resistant or immune species in future stands.

Littleleaf will continue to present a hazard to shortleaf pine production on sites where it now occurs. After cutting has been adjusted to prevent loss of the present crop, little can be done to insure successive crops of pine free from disease. Except on the worst littleleaf sites, shortleaf and loblolly can be managed as a short rotation crop, the disease hazard predictable from the performance of the present stands.

Older Stands that Have Remained Healthy

Within the littleleaf belt there are numerous stands that have remained healthy up to 40 or 50 years of age or were healthy at the time of harvest. Such sites present little hazard from littleleaf and can be managed on the basis of normal shortleaf stands outside the littleleaf belt.

Succeeding generations of pine on these sites should be free from littleleaf because soil conditions that predispose the species to attack probably are unfavorable for damaging activity of the root parasite.

Healthy Stands up to 40 Years of Age

The delayed onset of littleleaf in many stands and its increased prevalence in the 30 to 50-year age classes make it difficult to predict the future of young stands in respect to the disease. However, the soil and site studies already described offer a means of measuring the relative hazard for different stand conditions. Another indicator of the disease hazard is the growth response of individual trees. Stands in which littleleaf may eventually develop usually show an uneven growth response of individual trees as the threshold of age for symptom expression is approached. Any stand not yet showing littleleaf symptoms should be considered suspicious if bushy, stunted, yellowish-green trees develop among the more normal individuals. This unevenness of growth between dominant and codominant trees is probably the result of root injury that eventually leads to littleleaf.

Examination of soil conditions under young stands offers a means of predicting the potential littleleaf hazard. Sites rating over 75 on the littleleaf hazard rating scale should remain relatively free of littleleaf indefinitely. Those rating from 50 to 75 may develop light to moderate littleleaf after they are 30 years of age. Stands originating on badly eroded sites having heavy exposed subsoil must be considered poor risks from littleleaf at an early age.

After the littleleaf hazard for a given stand has been determined, management plans can be more accurately charted. Under such plans littleleaf sites would be used largely for short-rotation products such as pulpwood.

Recently Abandoned Fields and Areas in Need of Planting

There are thousands of acres of abandoned farm land within the littleleaf belt, many of which will reseed naturally, mainly with shortleaf pine. Eventually thousands of acres more may be retired from cultivation; on these areas and on poorly stocked forest land, there arises the question of the best species to favor in planting programs. For many reasons loblolly pine has been the preferred species for planting. Particularly because of the danger from littleleaf, several States have practically discontinued the production of shortleaf pine in their forest tree nurseries.

Experience has shown that loblolly pine is much more severely damaged by ice than shortleaf throughout the littleleaf belt. Damage in some instances has been so serious as to cast doubts on the wisdom of planting loblolly in those parts of the Piedmont where severe ice storms are frequent.

By the use of the littleleaf hazard rating scale, the expected performance can be estimated with respect to littleleaf of shortleaf pine on any site. Little risk would result from planting shortleaf on sites with a rating of over 75 on the scale. Likewise, shortleaf would be expected to do well up to 30 to 50 years on sites with a rating between 50 and 75 on the scale. Sites with a rating below 50 would be considered too hazardous because of littleleaf to warrant planting shortleaf pine.

The foregoing should not be considered a blanket recommendation on sites for planting shortleaf pine. However, in arriving at a decision on what to plant, littleleaf should not be the deterrent factor in discriminating against shortleaf on the better sites. In view of the ever present threat of recurring ice damage to loblolly throughout much of the littleleaf belt, species selection for planting deserves careful attention.

The major aspects of shortleaf pine silviculture in the littleleaf belt, as determined by 12 years of research and experience, may be summarized as follows:

(1) How to recognize a littleleaf site.--A rough estimate of the littleleaf potential of an area can be obtained by noting the location of the area with respect to the littleleaf belt (fig. 1) and the soil series (table 2). A refinement of this estimate can be obtained by the use of the field guide to littleleaf hazard, which is based on measures of internal drainage and erosion (fig. 3).

(2) How to manage timber on a littleleaf site.--If a site currently supports a diseased stand, cutting schedules are offered, depending upon littleleaf severity. The cutting of such declining trees reduces mortality both from littleleaf and from bark beetles, which often build up in stands supporting many diseased trees. These salvage cuts should also be aimed at increasing the component of other pine species, redcedar, and the soil-building hardwoods such as yellow-poplar, dogwood, and hickory.

Where special values are involved, the use of fertilizers may be justified. Inorganic fertilizers high in nitrogen (at the rate of at least 250 pounds of N per acre) have proved very effective in preventing littleleaf among the healthy trees on a littleleaf site and also in inducing recovery in trees with early symptoms. A fertilizer composition of 5-10-5 at the rate of 1 ton per acre, plus 750 pounds of ammonium sulfate per acre, will arrest the decline of many littleleaf stands for several years.

(3) How to manage shortleaf pine on non-littleleaf sites in the Piedmont.--When the use of the littleleaf distribution map, knowledge of soil series, or use of the littleleaf field guide and stand characteristics indicates little danger from littleleaf, shortleaf pine may be safely grown to an age of 60 to 80 years and perpetuated in succeeding generations by accepted methods of regeneration (6). This holds for most of the Piedmont and for many upper Coastal Plain soils other than those of alluvial or colluvial origin.

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Agriculture-Asheville

STATION PAPER NO. 26 AUGUST 1953

NATURAL REGENERATION OF LOBLOLLY PINE IN THE SOUTHEASTERN COASTAL PLAIN

BY

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By

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Loblolly pine timber makes up the largest part of the southern softwood timber supply. Within its range from New Jersey to Texas this species is the source of raw material for most of wood-using industry, and after harvest much of the land from which these trees are cut is left in need of reproduction to maintain a continuously productive forest. When these areas fail to seed in promptly to pine they aggravate the hardwood problem. They reduce future yields where an insufficient stand of reproduction develops. Dollar-wise these failures and partial failures represent an annual loss which conservative figuring places in the millions. Therefore, successful bridging of the gap between harvest of the old and establishment of the new stand is big business and worthy of concentrated attention from foresters and landowners alike.

The obvious remedy is planting. However, practical considerations limit planting to a partial solution at best. Of immediate importance is the time required to build up nursery capacity for such a tremendous undertaking. A serious obstacle is the reluctance of many landowners to invest in planting when examples of successful natural seeding are common. Taking into consideration these factors and others, a realistic appraisal must reach the conclusion that both planting and natural seeding will be used to reproduce cutovers in loblolly pine, and that we need to know how to handle both successfully. The purpose of this paper is to summarize some of the recent research in the Southeast which can contribute to the successful use of natural seeding. Details regarding most of the practices mentioned can be obtained from publications listed in the bibliography.

SEEDING CHARACTERISTICS OF LOBLOLLY PINE

The seed supply is of first importance in reproduction cutting because insufficient seed is certain to produce failure. The required amount varies tremendously from place to place, depending on the condition of the surface on which the seed falls. But where this seedbed is favorable and where losses from birds and rodents have not been large, a minimum of 25,000 sound seeds per acre has been required to produce a satisfactory stand of seedlings. The seedbed conditions on many tracts after logging will push this requirement up to 50,000 sound seeds or more.

In good seed years a mature stand will furnish this much seed and often several times this much. A 70-year-old unthinned sawtimber stand in North Carolina produced 260,000 sound seeds per acre in 1936, and a 90-year-old unthinned stand in the same state equalled this production in 1947. However, poor seed years are about as likely to occur as good ones, and in poor years the stands noted above produced 13,000 and 28,000 sound seeds per acre. Size and condition of the timber were ideal for seed production in these tracts. A more typical 50-year-old sawtimber stand in coastal Virginia produced 20,000 sound seeds in 1951, which was rated as a good year in that locality. It can easily be seen, therefore, that because of the class of timber or the general level of cone crop, years are common in which four, six, or eight seed trees will produce less seed than is needed and entire stands just reaching sawtimber size will often fail to do so.

Because seed is commonly the critical item in regeneration, characteristics of individual trees which indicate large seed-bearing capacity may provide valuable guides to marking practice. The best evidence of a tree's ability to produce seed has been found to be the presence of old cones in the crown -- the more old cones the greater assurance of fruitfulness. Cones of loblolly pine remain on the tree for as long as 3 years after they open, thus providing a key to productivity even when the current crop is poor. Another useful but less reliable indicator of the capacity to produce cones is trunk diameter. Trees 14 inches in diameter or larger which have old cones in the crown are the major seed producers and may be selected as seed trees. If seed is to be obtained from strips or blocks of uncut timber or from a heavy residual stand as in selection cutting, recognition of the fruitfulness of individual trees is not such a critical factor as when seed trees must be chosen. However, familiarity with characteristics of desirable cone-bearers is usually helpful when timber is marked for any type of reproduction cutting.

The usual time of seedfall and related matters often have a bearing on forest practice, particularly on the timing of seedbed preparation. Loblolly cones open on the trees in the latter half of October or first part of November, depending on the weather and the latitude where they develop. A general rule for flight of pine seed--that the effective seeding distance is within twice the height of the seed tree--seems to apply very well to loblolly. Most of the seeds fall shortly after the cones first open, and by the end of December only about 15 percent are left. These continue to be released through the winter and early spring. Therefore, practically all the seed from the stand is on the ground for several months before germination begins.

SEEDBED REQUIREMENTS

Next in importance to an adequate supply of seed is a favorable surface on which the seed can germinate. Mineral soil has been found to

be the best seedbed for loblolly pine in a number of special studies. A check of this conclusion on several hundred acres of cutover areas in the Bigwoods Experimental Forest[1/] showed that 9 seeds produced a seedling the first year where the litter had been disturbed and that over 40 were required on undisturbed areas or slash piles. Where the litter and slash had been burned off before seedfall, 15 seeds were needed to produce a seedling. The condition of the seedbed is therefore indicated quite readily by the proportion of the surface which has been disturbed to mineral soil. Fifty percent disturbance, well distributed, has permitted satisfactory stocking of reproduction on the cutting blocks sampled.

Some tracts will not be scarified enough through skidding, either because the volume to be removed is small or because the logs are lifted off the ground. Other areas will have such a poor seed source that efficient use must be made of all that is available. Various means of improving the seedbed on these tracts are being used effectively under a variety of conditions. These are combined operations in which the competition from inferior species is reduced at the same time the surface of the soil is disturbed.

Where competing stems are small (under 6 inches in diameter) a crawler tractor pulling a bush-and-bog disk harrow can cover an acre per hour of operation as a prelogging treatment (fig. 1). The same equipment

Figure 1.--Scarification before logging to improve seedbed conditions and reduce competition. A stump is dragged behind the disk to increase disturbance of the litter and root mat.

1/ Maintained by the Southeastern Forest Experiment Station in cooperation with Camp Manufacturing Company, Inc., Franklin, Va.

is not so effective after logging because the stumps may hang up the tractor or break disks, and slash concentrations must be avoided. Where larger competing stems are abundant, especially on areas which several years before failed to reproduce successfully, a bulldozer has been used to clear about half an acre per hour (fig. 2). Stumps offer less trouble for this machine after logging. Techniques for the use of fire in the coastal plain have been developed for application both before and after logging but its use is restricted to localities in which weather, fuel types, method of management, distribution of ownership, and public policy are relatively favorable. Under the proper circumstances fire has been cheap and effective. Regardless of whether seedbed preparation consists of burning, disking, or bulldozing, it must be done before seedfall lest the treatment destroy or bury the seed (fig. 3). Winter logging also probably destroys some of the seed on the ground, but the extra supply from the whole stand more than makes up for this loss.

COORDINATING SEED SUPPLY WITH SEEDBED CONDITION

Successful regeneration is dependent to a large extent on occurrence of adequate seeding when the seedbed is right. If seed comes a year late, rapid deterioration of the seedbed may reduce its effectiveness. In coastal North Carolina disturbed seedbeds between one and two years old have produced only a third as many seedlings from a given amount of seed as those less than 1 year old. Only one-tenth as many seedlings were produced on areas scarified 2 years before they were seeded. Competitive sprout growth adds to the difficulty of establishing reproduction after the first seedfall has gone by. Therefore, practical methods of bringing together a good cone crop and a favorable seedbed should be effective aids to successful reproduction cutting.

Use of Cone Crop Forecasts

Advance notice of the size of the next cone crop can be used under some circumstances to produce a favorable combination of seed supply and seedbed conditions. Cone crop estimates are being obtained long before seedfall by many of the state forest tree nurseries as part of their cone collection activities. In each of the past 2 years the North Carolina and Virginia State Forest Services have cooperated in making a cone crop forecast for the coastal plain a year before the cones were due to ripen, by counting conelets on samples from trees cut on logging operations. Others may be obtaining similar information. Although wide dissemination of these predictions has not been practiced in the past because the reliability of methods was under test, interested landowners can count on better guides to the size of future seed crops as more experience is gained in the use of forecast methods.

Figure 2.--Ideal seedbed conditions produced by bulldozer.

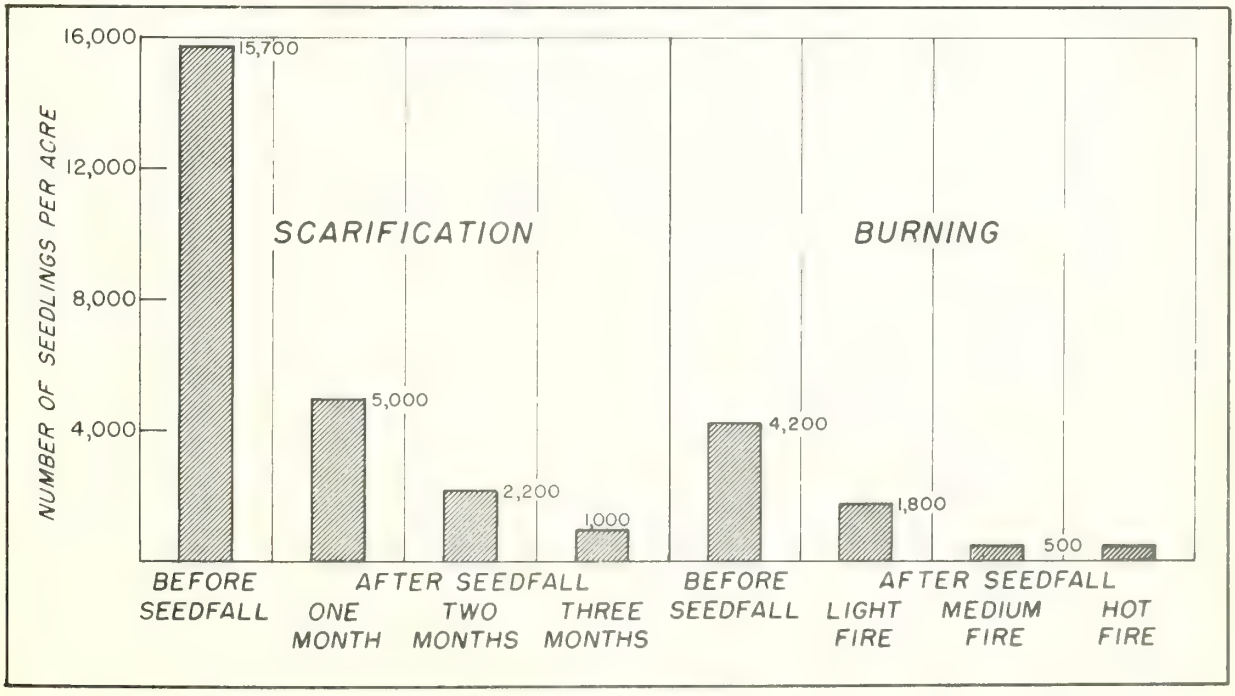

Figure 3.--Effect on seedling establishment of time of scarification and intensity of burn in relation to seedfall. Data on burning are from Chaiken (1).

The use of this information may be found essential to successful seedbed preparation in some localities. It may also influence cutting schedules. In fact, some landowners now plan to cut only when a good cone crop is in prospect. There is no better solution to the problem of seed supply on tracts having poorly stocked stands of pine where there is severe brush or hardwood competition. However, all cutting can't be scheduled for good seed years, because industry needs wood every year and at all seasons and a large part of it must come from reproduction cuttings. Advance notice of the size of the next seed crop is often useful but should be considered only one of several aids to more successful reproduction cutting.

Stimulating Seed Production Through Release

Planned cutting in a good seed year will increase the chances for successful reproduction on some of our forested acreage. On most of the rest, means must be used to obtain better seed supplies than will occur naturally. Research with a number of species has indicated that injury to the bole or applications of fertilizer may be practical ways of doing this, and limited trials have shown some promise for the success of these treatments on loblolly pine. However, the results obtained with these methods have been so overshadowed by the results obtained from crown release that crown release must be considered by far the best possibility for immediate practical application.

The fact that loblolly and other pines build up cone production after they have been isolated by cutting is not a new discovery at all. References to this reaction are common in the literature. The increase in number of cones produced has been attributed to a build-up of crown size and perhaps stored food reserves over relatively long periods such as 5 or 10 years. Observations during the past 5 years, however, have shown that the relationship between treatment and increased cone production is much more direct, is not based primarily on greater crown size, and will operate in generally poor seed years as well as in good ones (table 1). These facts can be of tremendous importance in the development of more reliable methods of reproduction cutting.

Release has caused as much as twenty times normal seed production on large overmature seed trees. It has doubled production on trees of minimum cone-bearing size in a generally poor seed year. Its effects have been observed on loblolly pine in Virginia, North Carolina, South Carolina, and Georgia, on longleaf pine in Alabama, and perhaps elsewhere within the range of loblolly. No instance is known in which release has failed to increase loblolly pine cone production and increase it substantially in the first crop year that could be affected. Also, the effects last more than 1 year; certainly for 2 years at a maximum level, and probably for a third year at a lower level. These observations justify the conclusion that release of crowns is capable of providing enough extra seed to permit successful reproduction cutting in a generally poor seed year, and that the effects last long enough to allow considerable flexibility in cutting plans which include preharvest release as part of the regeneration cycle.

Table 1.--Indexes of seed production from uncut stands in the Bigwoods Experimental Forest compared with those for released seed sources, using a bumper crop (1947) as the base for comparison

Year	Total seed yield 1/			
	Unreleased stands		Released sources 2/	
	#1	#2	#3	#4
	- - - - - - - - - - - Indexes - - - - - - - - - - -			
1947	100	100	3/ 100	3/ 100
1948	17	17	110	106
1949	14	11	137	131
1950	42	54	168	73
1951	66	65	238	
1952	29	50	196	245

1/ Includes those empty and damaged seed which fell from cones.
2/ One fourth of stand in leave strips or scattered seed trees -- 8 per acre.
3/ Unreleased 1947 production as base.

One characteristic of southern pine cone formation must be kept in mind when any method of stimulating seed production is under consideration. More than 2 years are required for a loblolly pine cone to mature, so the response to any stimulus is certain not to affect the number of cones in the succeeding two cone crops (fig. 4). Stands partially cut during the growing season therefore show the effect of release in the third or fourth crop after cutting, depending on whether release came early or late in the season (fig. 5). The critical period seems to occur in late June or early July, probably varying somewhat from year to year. It is safe to count on an increase in the third succeeding cone crop if the trees are released before the end of May.

The exact amount of release required has not been determined. In the one closely controlled study which has been completed, the space cleared around each released tree was equal to $2\frac{1}{2}$ to 3 times its crown width, producing a cleared area averaging about 40 feet in diameter with the tree at the center. Less complete release provided by a general improvement cut has

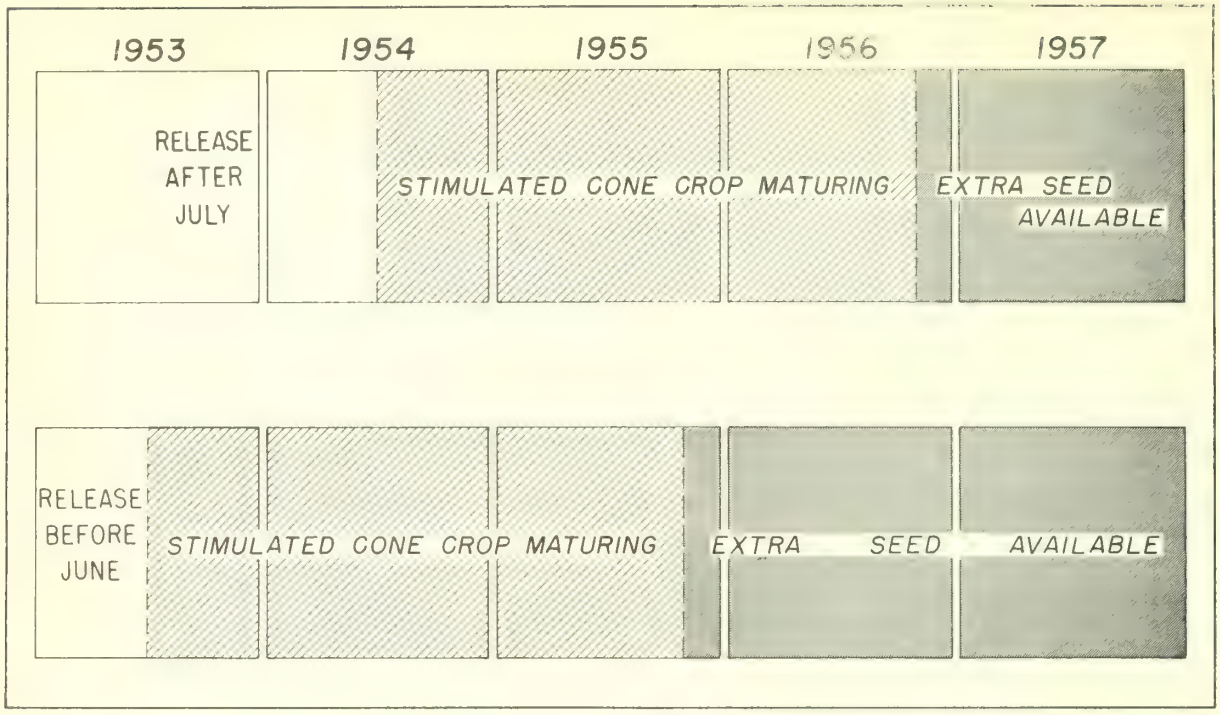

Figure 4.--Release before June, as compared with release after July, brings a stimulated seed crop one year earlier.

Figure 5.--Two conelets as they appear in April a year and a half before they ripen. Release at this stage comes almost a year too late to influence the size of this cone crop.

been observed to stimulate many of the trees left. In practice, if individual trees are selected for release it is probably sufficient to cut enough competitors so there is a 10-foot space forcrown expansion on all sides (fig. 6). If release is planned through a general partial cut any method of cutting will probably be satisfactory which produces an operable sawtimber volume.

Figure 6.--Seed tree released three growing seasons before removal of the stand. A, crown free on all sides. B, cleared area around base where cut averaged 550 board feet per released tree.

USE OF CONTROLLED REGENERATION IN PRACTICAL MANAGEMENT

The use that can be made in practical management of available information about seed supplies and seedbed requirements will be influenced to some extent by the type of silviculture used. Where selection management is the established policy, variability in the seed supply may be readily overcome by cutting on a short enough cycle so that freshly disturbed seedbed is produced in the openings in the same years that seed production is stimulated on surrounding trees. A 5-year cutting cycle should be fairly effective but a 4-year cycle would be better. Scarification of failed spots with heavy equipment seems possible in this type of forest but not the use of fire.

The number and size of trees to leave in cuttings of the seed-tree type has been under study for as long as this method of reproduction has been in use. Emphasis has usually been placed on determining the minimum which would give some assurance of providing seed. The value of the trees has been considered comparable to a planting cost to be carried as a charge against the reproduction, although there was hope that they could be salvaged later on. More precise information about seed and seedbed requirements has shown the value of additional seed trees to give greater assurance of adequate seeding. The rapid decrease in their effectiveness through seedbed deterioration has also suggested their prompt removal after reproduction is established. Instead of the minimum requirements most often thought of in the past, therefore, the most effective and economically sound approach probably is to plan for enough sawlog volume in seed trees to provide an operable cut after seedlings have been established. Eight, ten, or twelve trees to the acre can be left with this schedule of cutting in mind without considering them a financial loss and with greater assurance that they will provide enough seed for adequate stocking. If these trees are released by partial cutting 3 to 5 years before the final harvest, the combination of seed supply and seedbed thus provided is as nearly ideal as any known under the seed-tree system. Removal of the seed trees after seedlings are established will result in some damage to the young growth, but where the seedlings are 1 or 2 years old this can be confined to major tractor roads and loading areas. Trees can be felled toward or away from concentration points marked in advance, thus reducing damage to a minimum. Larger seedlings and saplings are more brittle and therefore more vulnerable. Possibility of drought losses during the first year's growth are so great that seedlings should be at least 1 year old before the seed trees are taken off.

Eight scattered seed trees have consistently produced more seed than one-fourth of the stand in leave strips where these types of cutting have been compared in North Carolina. Yet strip cutting where stands are uniform may be used for other reasons. Methods of stimulating seed production in the leave strips would be similar to the preharvest release of seed trees, and timing of the final cut the same.

During the first years after they are established, stands of loblolly pine seedlings are vulnerable to fire and may be completely wiped out. In the past, seed trees have provided some assurance that a disastrous fire would not leave a tract completely unproductive. This was not perfect

insurance by any means, because a poor seed year could easily coincide with the year of the fire. But in a time of low stumpage values as compared with planting costs, and in the days of commonly high fire risk, even partially effective insurance was essential. Now that stumpage values are higher and fire risks lower, the justification for leaving insurance trees is much less clear-cut.

The general principles regarding seed supplies and seedbed conditions which will reduce the uncertainty in reproduction cuttings of loblolly pine can be summarized as follows:

For all-aged management

1. Harvest on a short enough cycle so that seed production stimulated by release will still be effective at the time of each cut.

For even-aged management

1. Cut poorly stocked or depleted stands in years of generally heavy seed production.

2. Leave a relatively heavy seed-tree stand and plan to harvest it as soon as reproduction is well established.

3. Where stand conditions are suitable, stimulate the seed source through preharvest release 3 to 5 years before the reproduction cut.

4. If local policy and experience are favorable, use scarification equipment or fire where seed supplies are likely to be inadequate.

SEEDLING ESTABLISHMENT

The object of all plans for reproduction cutting is a well-stocked stand of seedlings which are free to grow. For most conditions of ownership this means about 750 seedlings per acre, well distributed, with no overhead competition. Some landowners will be satisfied with fewer seedlings and some will want more, but 750 is probably a fair average. However, initial establishment of several thousand seedlings per acre usually is required to reach this goal. Uneven distribution, losses from various causes, and competing vegetation all reduce the effectiveness of the total number first established.

By far the most common problem encountered is the competition from residual hardwoods and hardwood sprouts (fig. 7). The larger residuals reduce the effectiveness of the seedling stand through competition for light and moisture and also by acting as a physical barrier to normal height growth. They reduce the area available for production of pine by approximately the area under their crowns. It's not unusual for this reduction to

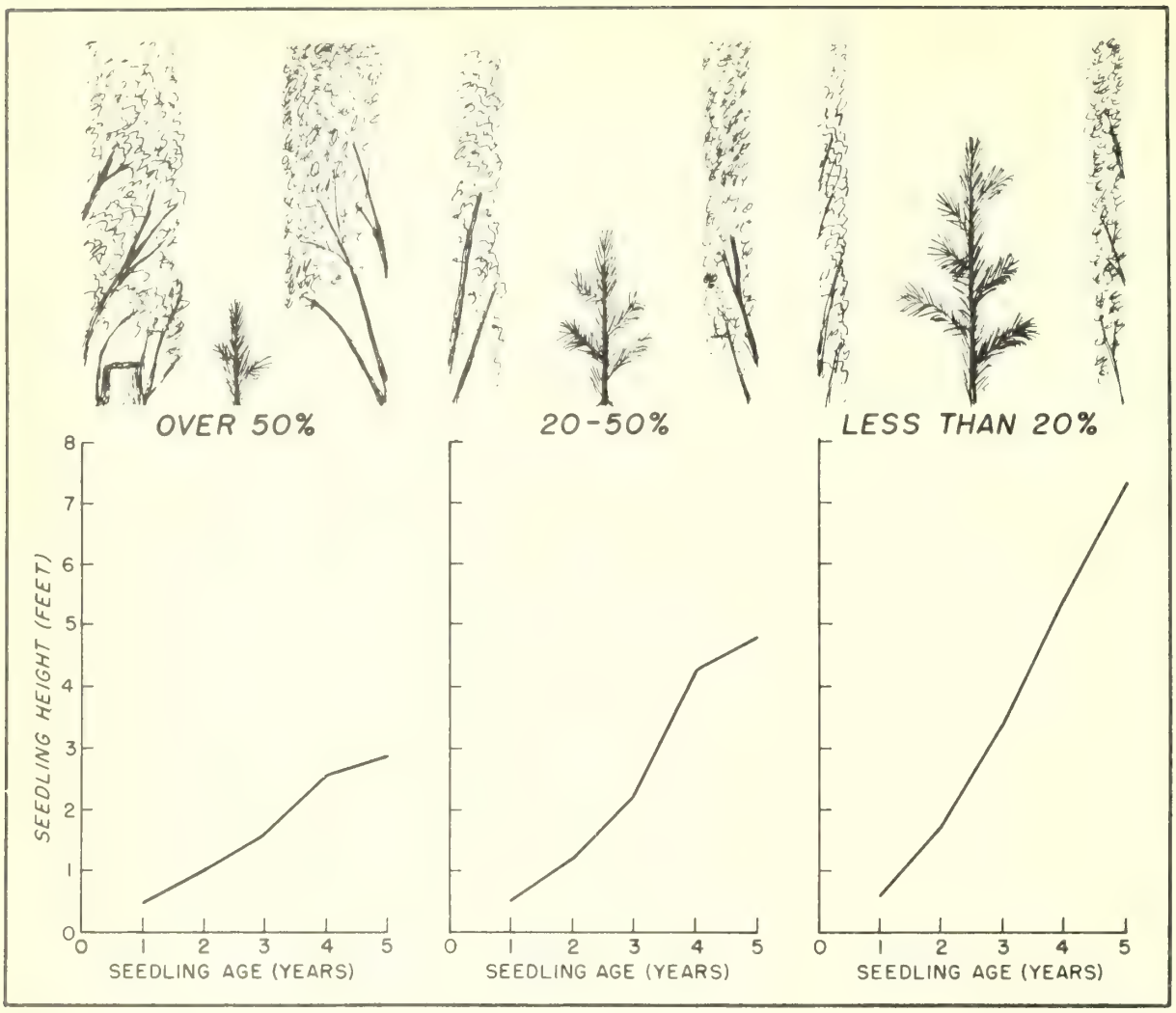

Figure 7.--Heights of loblolly pine seedlings 1 to 5 years old in the Bigwoods Experimental Forest growing under 3 conditions of overhead shade. Shade from competitors $\frac{1}{2}$-inch d.b.h. and larger classified on 0.01-acre plot immediately after harvest of pine stand--seedling measured was tallest found on central 0.001-acre plot at the end of each growing season.

be as much as a fourth of the growing space. Liberation of seedlings from these larger competing stems can be accomplished through girdling, or poisoning with 2-4-5,T or Ammate. Recovery of seedlings thus liberated has been rapid (fig. 8). Even those which have been suppressed for long periods quickly build up normal crowns and begin rapid height growth.

Smaller competing stems can be handled most effectively by methods which also prepare the seedbed. Logging itself may reduce the hardwood cover effectively in many instances. If there is no delay in their establishment, pine seedlings usually compete successfully with sprouts from hardwoods that are cut or broken off, or killed back to the ground. In general, sprouts from red maple and sweetgum are more serious competitors than those from the oaks. Usually by the end of their fifth year and often sooner the success or failure of pine seedlings in overcoming competition becomes obvious. Where help must be provided, it can be given by severence of competing stems or by treatments with chemicals.

Forest managers who use the aids to successful reproduction cutting discussed in this paper will have to give a little more than average attention to thorough planning, careful supervision, and the details of intensive management. Heavy expense is not involved. Nevertheless, a period of trial is needed during which the results of more careful work accumulate to justify whatever extra costs there are. Numerous examples show that too little attention to the requirements for reproduction can lead to reduced yields and expensive rehabilitation projects. More examples of intensive practice are needed to emphasize the importance of keeping pine timberlands in good growing condition.

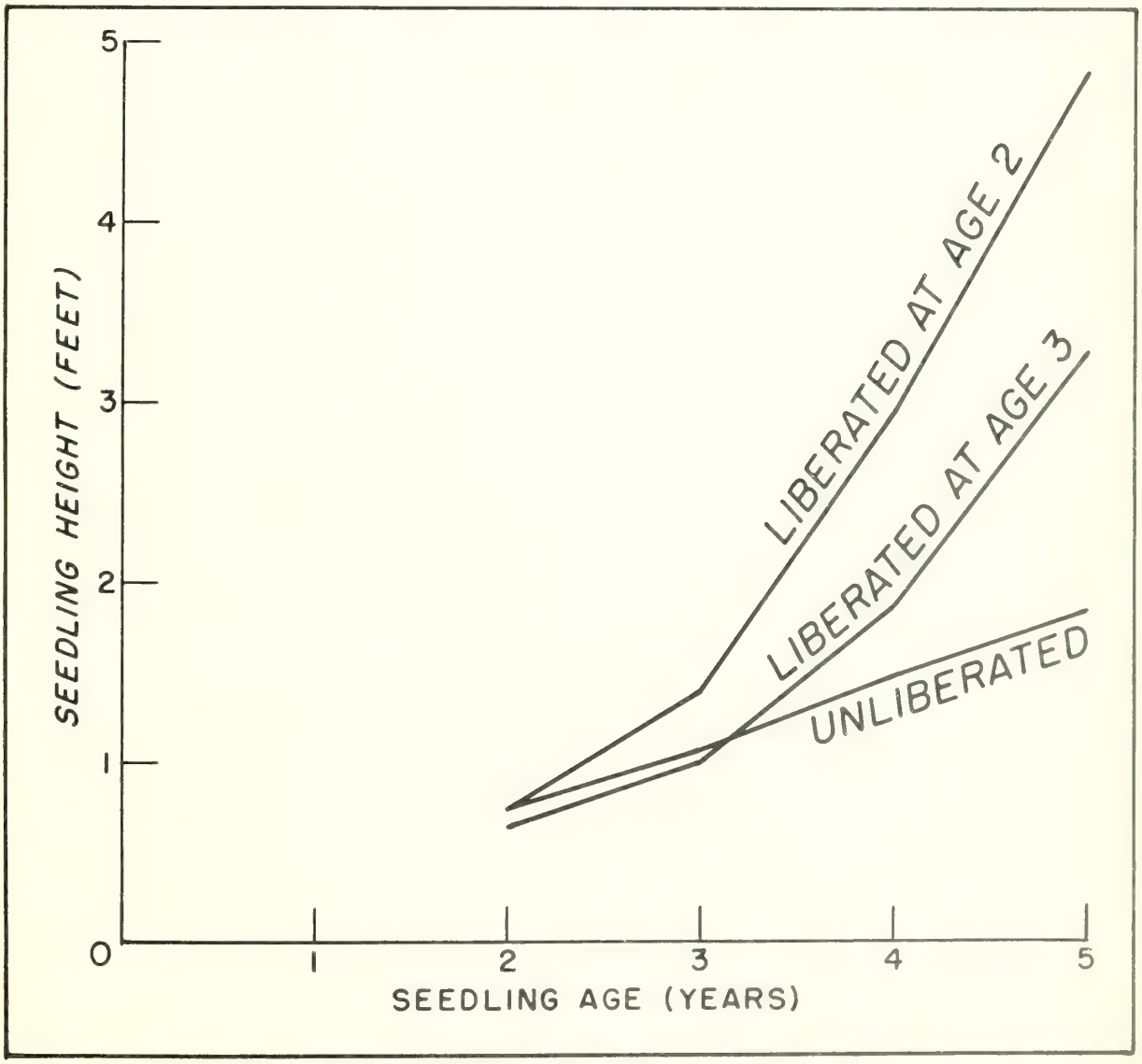

Figure 8.--Heights of seedlings 2 to 5 years old in the Bigwoods Experimental Forest with and without liberation from overstory hardwoods 4 inches and larger.

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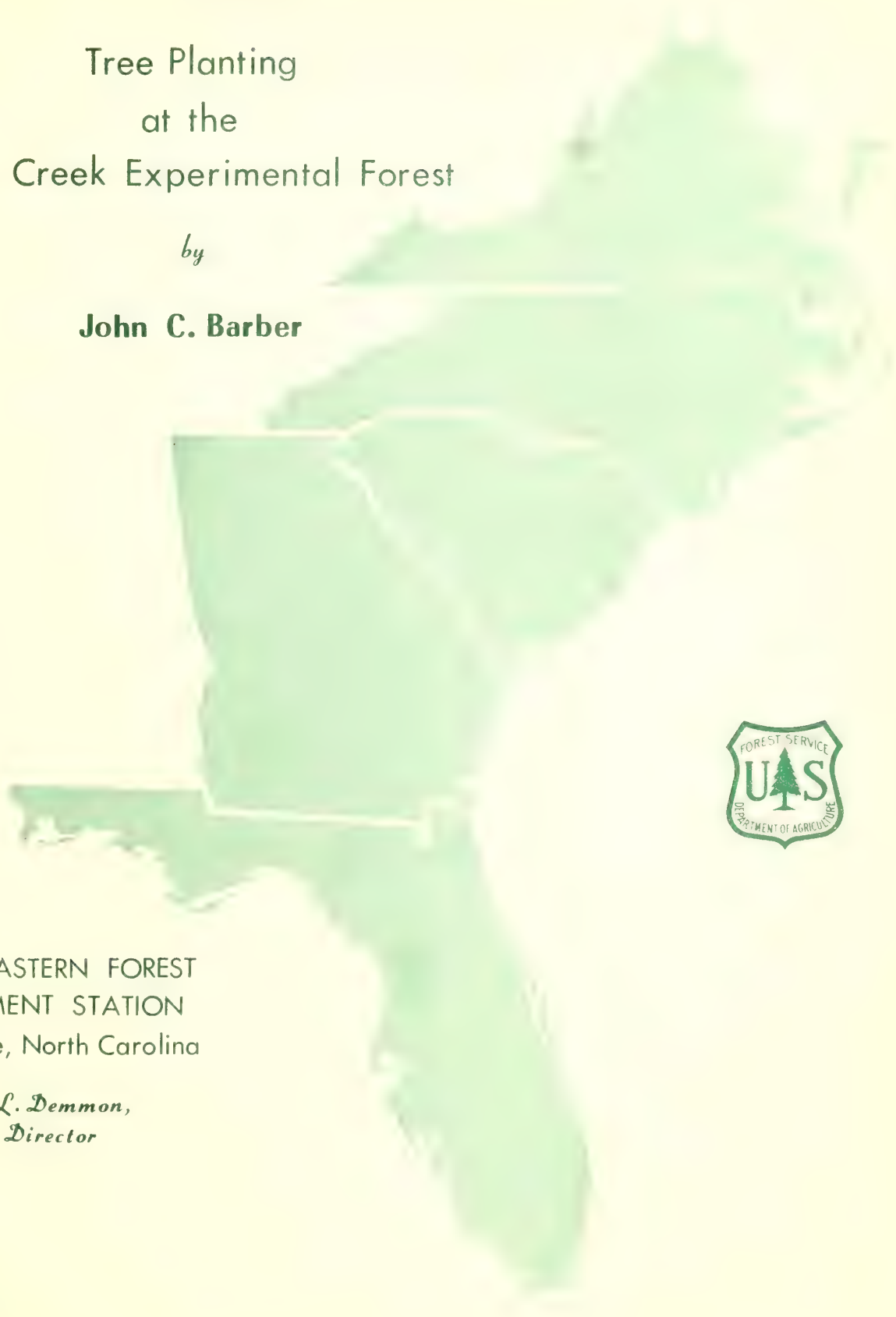
Agriculture-Asheville

STATION PAPER NO. 27 AUGUST 1953

Tree Planting at the Bent Creek Experimental Forest

by

John C. Barber



SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. Department of Agriculture - Forest Service

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TREE PLANTING AT THE BENT CREEK EXPERIMENTAL FOREST

by

John C. Barber

INTRODUCTION

Foresters everywhere are becoming increasingly conscious of the potentialities of tree selection and breeding. In the quest for suitable breeding material, many of the plantations of the past are assuming importance, for each plantation of introduced species may provide information on its adaptability to a certain area and the desirable and undesirable traits which it may manifest in its new environment.

One group of such plantations is on the Bent Creek Experimental Forest near Asheville, in Buncombe County, North Carolina. The Bent Creek Arboretum originally contained 53 species on 69 plots. Many of these trial plantings failed, and several were destroyed. At present the area contains 32 species on 44 plots. There were 11 native species planted, 25 species from other regions of the United States, and 17 species from Europe and Asia. Seeds for some of the exotic plantings were obtained from planted trees in the United States and Canada. The plots are grouped on an area of about 10 acres along Bent Creek. Several informal examinations have been made of these plantings but no formal report has been presented since 1932.[1/] Thus, the development of these plots has not been systematically recorded; nor have they received optimum release and thinning in many cases.

HISTORY OF THE ARBORETUM

The Bent Creek Arboretum was begun informally in 1926 by F. W. Haasis, who made eight small plantings of seedling trees from seed of various sources outside the region. In 1927, I. H. Sims continued the work with the establishment of 15 additional plots. During these first years there was no formal plan of development, and the plots established were marked with temporary

1/ Bradshaw, D. E. and E. H. Bomberger. Examination of Bent Creek plantations. Southeastern Forest Expt. Sta., unpublished office report, 1932.

wooden corners only. In the spring of 1928 A. L. MacKinney established eight more plots and marked them with permanent iron stakes at the corners. He set out twenty-two additional plots in 1929 and 13 in 1930. The final plantings in this series were made in 1931, with the establishment of three small plots and the replanting of several plots which had failed.

A complete record of all plots was made in 1932, insofar as possible, and a brief report was prepared. Subsequent to this 1932 report, the arboretum received little attention. There were no further plantings until 1950, and during this period no additional observations were recorded. In the spring of 1952, Dorman listed the species which had been planted at Bent Creek.2/ This listing raised questions about the performance of exotic species and species native to the United States but planted outside their natural ranges.

During the late summer and fall of 1952 all plots were examined and the surviving trees measured. The diameters of all trees were recorded and, where possible, the heights. On many of the plots the density of the crowns made complete and accurage height measurements impossible, so that for these plots the average height given is based on a selected sample of dominant, codominant, and intermediate individuals.

Throughout the arboretum, which had been established in abandoned fields, several species of native trees seeded in. On several of the plots this severe competition has made a serious effect upon growth and mortality of the introduced species. The faster-growing and more tolerant conifers apparently were not affected very much because they were able to close the crowns rapidly enough to smother competition or prevent its establishment. The plantings were all spaced 6 by 6 feet.

SOIL AND CLIMATE OF THE ARBORETUM

The soil in the arboretum is classed as Tate silt loam. This is a colluvial soil occurring at the bases of slopes. Tate silt loam is a productive soil with good to excessive external drainage and good internal drainage. The slopes adjacent to the arboretum are of Halewood stoney loam, steep phase. In general, the Bent Creek Arboretum is relatively level, with only small slope variations on a few plots. At time of planting, several shallow ditches were cut to supplement natural drainage.

The climate at Bent Creek can be considered moderate. Based on 12 years of weather observations, the average annual precipitation is approximately

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2/ Dorman, Keith W. Directory of forest genetics activities in the South. Southeastern Forest Expt. Sta. Station Paper 17. 17pp. 1952.

44 inches, with a range of from 38 to 55½ inches. The average minimum temperature recorded is 3 degrees F., with a range of from -10 degrees F. to 10 degrees F. The average maximum temperature is 94 degrees F., with a range from 90 degrees F. to 98 degrees F. Average killing frost dates are October 13 to April 28, with ranges of September 27 to November 6, and April 17 to May 14. Elevation of the arboretum is 2050 feet. Location is Lat. 35° 30' N., Long. 82° 38' W.

GROWTH OF TREES IN THE ARBORETUM

On the basis of the 1952 observations, the plantings may be arbitrarily divided into three groups: successful, existing but unsatisfactory, and unsuccessful. Table 1 lists the plantings which have done well and may be considered successful. Table 2 lists the plantings which still exist but have not demonstrated vigor or adaptability to the site and are unsatisfactory. Table 3 lists those plantings which can be considered failures. It must be kept in mind that this is only one test planting and that the critical factors affecting success or failure may be peculiar to this immediate area. The Bent Creek Arboretum lies in a frost-pocket which would seriously affect frost-sensitive species. It is subject to late frosts which damage the native species. Early reports indicate browsing by deer on some plots, and present observations indicate damage has also been inflicted by deer rubbing their antlers. The severe drought of 1930 is recorded as greatly affecting mortality, but the record made in that year does not mention any species in particular.

PLANTINGS OUTSIDE THE ARBORETUM

In addition to the arboretum plantings, several more extensive field plantings were made of a number of species, both native and introduced. The essential measurements on several of these plantations are recorded in table 4. A plantation of 300 Pinus rigida made in 1929 has scattered survivors of poor form and vigor, and is classed as a failure. Another failure was a plot of 1200 Abies balsamea planted in 1930. Early survival was very poor, and in 1952 no survivors were located. Several plantations of Liriodendron tulipifera were made, both pure or in mixture with Juglans nigra, Gleditsia triacanthos and Quercus alba. All of these plantations were made where there was an abundant supply of native Liriodendron seeds. The yellow-poplar is present, but the intermixing of planted and volunteer seedlings prevents an evaluation of these plots. The Juglans is recorded in table 4 and Gleditisia has no survivors. Because the plot containing Quercus alba was not accurately located, no evaluation could be made; however, an examination in 1932 records 88 percent survival.

Table 1.--Successful plantings in the Bent Creek Arboretum

Species	Seed source	Trees planted	Age in 1952	Survival & growth to 1932: Survival	Average height	Maximum height	Survival & growth to 1952: Survival	Ave. dbh.	Max. dbh.	Ave. hgt.	Max. hgt.
		No.	Yrs.	%	Ft.	Ft.	%	Ins.	Ins.	Ft.	Ft.
Acer saccharum	Varna, N. Y.	100	27	53	2.3	7.2	35	2.7	5.8	40	46
Acer saccharum	Unknown	85	26	59	.8	1.8	42	1.3	4.8	18	46
Albizzia julibrissin	Unknown	26	24	100	2.8	5.2	65	1/4.5	7.2	30	32
Albizzia julibrissin	Unknown	24	24	92	5.8	7.5	58	1/3.8	7.6	30	37
Chamaecyparis thyoides	Dismal Swamp, Va.	61	26	84	9.2	13.5	2/31	6.0	8.7	48	55
Ilex opaca	Pender Co. N. C.	16	22	3/81	1.1	2.3	94	3.3	5.6	19	22
Ilex opaca	Pender Co., N. C.	8	22	100	.9	1.5	100	3.7	5.0	17	22
Libocedrus decurrens	Washington	18	26	44	3.2	7.3	17	8.7	13.9	27	35
Liriodendron tulipifera 4/	Local	53	25	89	3.5	9.5	70	5.9	11.7	42	60
Picea abies	Angus, Ontario	43	22	60	.5	.8	30	5.2	8.2	24	36
Picea glauca	Unknown	48	24	3/85	1.0	2.2	5/94	3.4	8.0	19	31
Picea glauca	Unknown	24	24	92	1.1	1.8	87	4.2	5.6	26	32
Pinus densiflora	Japan	44	25	98	5.3	8.3	77	5.1	7.8	38	45
Pinus resinosa	Vermont	140	26	51	5.4	7.8	27	7.5	10.6	39	47
Pinus resinosa	Michigan	36	26	30	3.4	5.6	14	7.0	7.9	28	33
Pinus resinosa	Essex Jct., Vt.	100	27	29	5.6	8.5	21	6.2	8.4	32	38
Pinus resinosa	Glenn, Minn.	100	27	30	4.5	7.5	19	5.7	7.4	27	35
Pinus regida	Unknown	24	24	100	3.4	6.1	62	5.1	9.1	40	48
Pinus regida var. serotina	Burgaw, N. C.	62	23	92	2.3	7.0	61	8.0	11.8	52	58
Pinus sylvestris	Unknown	65	24	91	1.5	3.4	57	3.4	5.5	20	30
Pinus taeda	N. C. (Coastal Plain)	47	23	87	5.2	8.2	70	8.6	14.1	56	62
Thuja occidentalis	Cornell, N. Y.	100	27	97	3.3	7.3	74	4.9	9.6	29	41
Thuja occidentalis	Cornell, N. Y.	10	27	100	5.3	8.3	90	5.7	7.8	26	29
Thuja occidentalis	Cornell, N. Y.	135	26	96	1.4	3.6	84	4.3	7.0	28	33

1/ All trees were multiple stemmed; therefore, these measurements were based on the largest stem of each individual.

2/ This species is being attacked by a white, stringy root and butt rot caused by Fomes annosus. (See Toole, E. R. and Boyce, J. S. Jr. Fomes Annosus on white cedar. Plant Dis. Rptr. 36(8):330. 1952) Mortality has been high and the fungus is progressively destroying the plot.

3/ This plot was probably replanted, because there are more trees present now than in 1932.

4/ Evaluation of this planting was complicated by the presence of native volunteers; therefore, the measurements cited are based on a selected sample of the ten best trees believed to have been planted.

5/ A canker believed to be caused by Cytospora sp. is present on one tree. There are no fruiting bodies present on the canker and positive identification has not been made.

Table 2.--Existing but unsatisfactory plantings in the Bent Creek Arboretum

Species	Seed source	Trees planted	Age in 1952	Survival & growth to 1932			Survival & growth to 1952				
				Survival	Average height	Maximum height	Survival	Ave. dbh.	Max. dbh.	Ave. hgt.	Max. hgt.
		No.	Yrs.	%	Ft.	Ft.	%	Ins.	Ins.	Ft.	Ft.
Castanea crenata 1/	Unknown	25	24	88	2.8	5.3	88	0.9	2.8	10	20
Castanea mollissima 1/	Unknown	23	24	91	3.1	4.1	91	1.6	4.1	18	36
Castanea mollissima 1/	China	13	26	85	4.3	6.8	85	2.8	6.2	24	43
Castanea seguini 2/	Unknown	5	24	80	2.1	2.5	60	--	0.5	5	7
Cercis canadensis	Unknown	21	24	90	1.5	2.7	29	1.6	2.8	18	22
Cornus mas	France	4	24	75	.4	.6	(3/)	--	--	--	--
Cornus sanguinea	France	2	24	100	1.6	1.9	(3/)	--	--	--	--
Cupressus macnabiana	Amador Co., Calif.	12	23	25	1.9	2.9	8	--	6.1	--	28
Gleditsia triacanthos	Unknown	48	24	96	1.9	7.4	2	--	6.1	--	48
Picea sitchensis	Unknown	84	26	18	1.5	2.8	12	2.5	5.1	12	18
Pinus densiflora	Japan	22	25	95	5.0	7.0	14	7.4	10.5	36	40
Pinus densiflora	Japan	37	24	97	3.7	6.3	49	4.8	8.0	36	41
Pinus echinata	Local	13	26	54	8.6	11.0	23	8.4	9.5	40	44
Pinus monticola	Unknown	70	26	53	1.7	3.7	13	3.3	5.2	19	24
Pinus palustris	Pender Co., N. C.	20	24	80	.2	.6	30	6.4	9.5	34	42
Pinus pungens	Mt. Mitchell, N. C.	36	23	92	1.9	3.1	8	6.4	7.0	31	36
Populus deltoides	Local	126	25	54	2.2	8.6	(4/)	2.4	4.4	24	28
Quercus montana	Local	27	24	81	.8	1.7	67	1.1	4.0	13	33
Rhamus purshiana	Roy, Wash.	10	26	70	1.2	2.0	60	.3	1.1	6	14
Rhamus purshiana	Roy, Wash.	10	26	70	1.3	2.8	20	1.1	1.9	15	18

1/ Evidence indicates that some of the stems now present are of sprout origin. Chestnut blight cankers are present on most of the individuals.

2/ All existing stems are of sprout origin and show evidence of infection by the chestnut blight fungus.

3/ The two species of Cornus are shrubby and have spread on the plot until it is impossible to make accurate observations on the original stems.

4/ This plot contains several individuals of P. alba which apparently were introduced in planting. Measurements are based on a selected sample. Numerous stems are present from root suckers of both species.

Table 3.--Unsuccessful plantings in the Bent Creek Arboretum

Species	Seed source	Date planted	Trees planted	Survival and growth to 1932: Survival	Average height	Maximum height	Survival in 1952
		Year	No.	Percent	Feet	Feet	Percent
Arbutus menziesi	Unknown	1929	3	0	--	--	0
Castanea crenata 1/	Unknown	1929	28	3	--	--	0
Castanea dentata	Eastern, N. C.	1928	4	25	--	3.0	0
Castanea mollissima 1/	Unknown	1929	26	11	--	--	0
Cercis sp. 2/	Brignoles, France	1929	12	0	--	--	0
Chamaecyparis lawsoniana	Eldorado Co., Calif.	1930	30	47	0.9	1.5	0
Daphne gnidium	France	1929	3	0	--	--	0
Fraxinus oregona	Newberry, Ore.	1930	16	81	.9	1.8	0
Ginkgo biloba	Washington, D. C.	1929	46	0	--	--	0
Larix leptolepsis	Japan	1928	27	37	2.2	6.6	0
Larix occidentalis	Coeur d'Alene Nat'l For., Idaho	1930	19	10	1.6	2.6	0
Pinus attenuata	Eldorado Co., Calif.	1930	84	38	1.6	2.4	0
Pinus caribaea	Louisiana	1927	7	71	5.0	6.7	0
Pinus contorta	Unknown	1927	18	78	1.2	2.9	0
Pinus contorta	Unknown	1926	48	72	1.6	4.2	0
Pinus contorta latifolia	Eldorado Co., Calif.	1930	46	93	.7	1.2	0
Pinus koraiensis	Korea	1929	50	16	1.1	1.9	0
Pinus nigra poiretiana	Unknown	1928	21	52	3.4	4.9	2
Pinus radiata	Placerville, Calif.	1929	1	0	--	--	0
Pinus sabiniana	Eldorado Co., Calif.	1930	12	50	2.5	2.9	0
Pseudotsuga taxifolia	Idaho	1929	50	52	.8	1.5	0
Quercus alba 2/	Local	1929	20	0	--	--	0

1/ Plot destroyed by road construction.
2/ Plot location was not found in 1932 or 1952.

Table 4.--Plantations on the Bent Creek Experimental Forest outside the arboretum

Species	Year planted	Trees planted	Estimated survival	Average d.b.h.	Average height	Maximum d.b.h.	Maximum height
	Year	Number	Percent	Inches	Feet	Inches	Feet
Pseudotsuga taxifolia	1929	108	2	--	--	1.5	10
Juglans nigra	1928	245	4	--	--	5.6	34
Liriodendron tulipifera 1/	1928	750	20	--	--	7.1	42
Liriodendron tulipifera 1/	1928	252	75	8.9	63	11.2	65
Pinus nigra poiretiana	1928	234	2	--	--	9.8	41
Pinus resinosa 2/ (A)	1931	258	20	7.1	25	7.9	28
(B)	1926	262	15	6.4	35	9.1	41
(C)	1926	364	30	4.8	31	7.7	41
(D)	1927	70	35	5.5	35	7.0	40
Pinus sylvestris	1928	966	25	6.0	28	8.3	31
Pinus densiflora	1931	200	30	7.0	34	7.6	36

1/ These plantations were in areas with an abundant natural seed source; therefore, in every instance there are numerous volunteers which complicate any attempts to examine and evaluate the original plantations.

2/ Seed sources: (A) Minnesota
(B) Cloquet, Minnesota
(C) Gerrish, N. H.
(D) Seed source unknown, stock from Mt. Alto, Pa.

The average figures of table 4 are from a selected sample of dominant and codominant individuals thought to be representative of the potential crop trees in each plantation. Where the plantation survival is extremely poor, only maximum individual measurements are stated, as it would be impossible to give a valid average based on such a small sample.

GROWTH OF RED PINE FROM DIFFERENT SOURCES

The plots of Pinus resinosa represent several seed sources and may be considered as a test along with those of the arboretum. Table 5 lists the comparisons of Pinus resinosa from several seed sources. Although variations between individual lots are quite marked, no regional trend is apparent. However, with the exception of the Cloquet source, the New England sources appear superior, especially in height growth. The Cloquet stock may owe its superiority to selection of seed source and not to geographic variability. The seed source information is not complete enough to evaluate this possibility.

Table 5.--Plantings of Pinus resinosa on the Bent Creek Experimental Forest

Location	Seed source	Date planted	Trees planted	Survival 1952	Ave. DBH	Max. DBH	Ave. hgt.	Max. hgt.
		Year	No.	Percent	Ins.	Ins.	Ft.	Ft.
Arboretum	Essex Jct., Vt.	1926	100	21	6.2	8.4	32	38
Arboretum	Glenn, Minn.	1926	100	19	5.7	7.4	27	35
Shut-in ridge	Cloquet, Minn.	1926	262	1/ 15	6.4	9.1	35	41
Shut-in ridge	Gerrish, N. H.	1926	364	1/ 30	4.8	7.7	31	41
Arboretum	Vermont	1927	140	27	7.5	10.6	39	47
Arboretum	Michigan	1927	36	14	7.0	7.9	28	33
Shut-in ridge	Unknown 2/	1927	70	1/ 35	5.5	7.0	35	40

1/ Survival percentage estimated because some of the plot boundaries could not be accurately located.

2/ Planting stock from nursery at Mt. Alto, Pa.

RECENT PLANTINGS ON THE EXPERIMENTAL FOREST

In the spring of 1951, a field test of Pinus resinosa was instituted with the planting of 6000 seedlings, 3-0 stock, produced from seed collected

in 1939 on the Chippewa National Forest, Minnesota, at an elevation of 1300 feet.

In 1949, another planting was made of 3900 Picea abies, 2-2 stock, as a Christmas tree plantation. The stock was furnished from the U. S. Forest Service nursery at Parsons, West Virginia. To date, survival and growth have been good. Some harvesting of small trees should begin in 1953.

Twenty-five seedlings of Metasequoia glyptostroboides were planted at the Bent Creek Experimental Forest in 1950. These seedlings were provided by Mr. Ralph W. Chaney, of the Museum of Paleontology, Berkeley, Calif. The seeds were collected in western Humpeh, central China in 1948. At the end of three growing seasons, 20 seedlings have survived and have an average height of 1.4 feet with a maximum of 2.8 feet.

In 1951 a test planting was made of two pine hybrids produced at the Institute of Forest Genetics, Placerville, California. The seedlings were transplanted to the field after 9 months in greenhouse flats. Plot B was again transplanted at the beginning of the third growing season in the field. Table 6 contains a summary of the measurements of all seedlings at the end of two growing seasons in the field.

Table 6.--Survival and growth of hybrid pines

Hybrid and parents	Plot A			Plot B		
	Survival 1/	Ave. hgt.	Max. hgt.	Survival 2/	Ave. hgt.	Max. hgt.
	Percent	Ft.	Ft.	Percent	Ft.	Ft.
Pinus rigida x Pinus taeda	65	1.4	2.3	88	0.9	1.8
P. rigida (parent)	67	(3/)	--	100	.5	.9
P. monticola x P. strobus	76	.4	.7	--	--	--
P. monticola (parent)	38	.3	.6	--	--	--
P. strobus (parent)	57	.4	.6	--	--	--

1/ Survival after 2 years in the plantation.
2/ Survival 1 year after second transplanting, based on number transplanted.
3/ Trees not sufficiently erect to permit height measurement.

It appears that the hybrid stock of Pinus monticola x Pinus strobus is not superior to the native P. strobus, though it is superior to its parents. A cross is now planned between native P. strobus from the Southern Appalachians and P. monticola. Pollen for this hybrid has been collected at the Bent Creek Experimental Forest and forwarded to Placerville for breeding purposes.

CONCLUSION

In conclusion, it appears that only about ten introduced species approach the native species in vigor and growth. Of these, three seem worthy of further investigation. The first, Chamaeyparis thyoides, (see figure 1) is subject to a root and butt rot in the arboretum, but on other sites it may prove satisfactory. If this disease is controllable, the species may be valuable for planting wet and poorly drained sites. The second and third species are Pinus taeda (figure 2) and Pinus rigida var. serotina. These two species are superior to any other of the test plantings and may in themselves be valuable for planting or for breeding purposes in the Southern Appalachians.

Several other species such as Picea abies, Picea glauca, Pinus resinosa (figure 3), Pinus densiflora, and Thuja occidentalis (figure 4) may not be valuable for forest planting, but adaptability to the area has been demonstrated to date, thus offering potential qualities for the forest geneticists to consider.

Figure 1.--Atlantic white-cedar (Chamaecyparis thyoides), age 26 years. Maximum height 55 feet, maximum d.b.h. 8.7 inches. Note mortality due to Fomes annosus.

Figure 2.--Loblolly pine (Pinus taeda), 23 years old. Maximum height 62 feet, maximum d.b.h. 14.1 inches.

Figure 3.--Red Pine (Pinus resinosa), 26 years old. Maximum height 47 feet, maximum d.b.h. 10.6 inches.

Figure 4.--Northern white-cedar (Thuja occidentalis), age 27 years. Maximum height 41 feet, maximum d.b.h. 9.6 inches.

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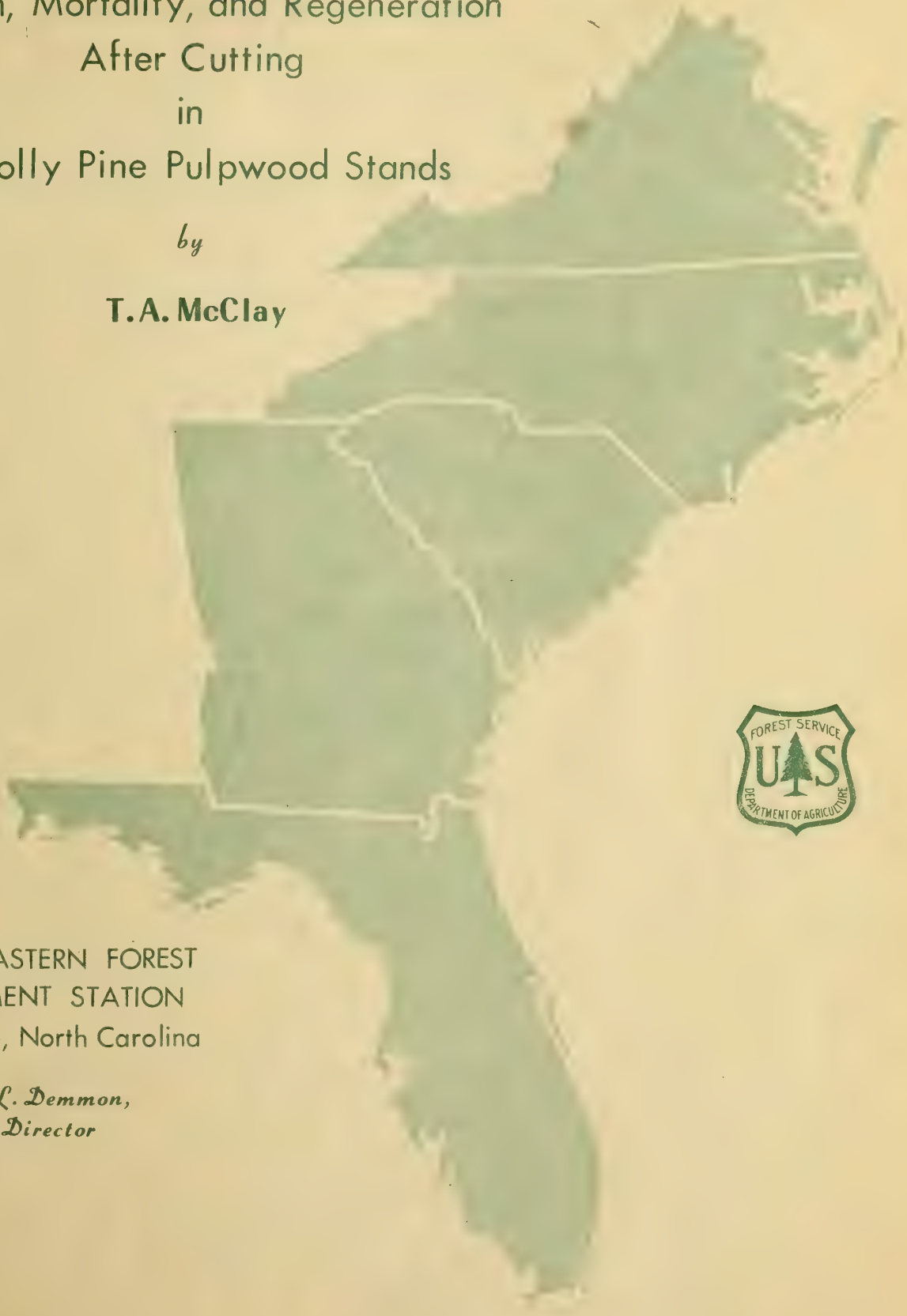
Growth, Mortality, and Regeneration After Cutting in Loblolly Pine Pulpwood Stands

by

T. A. McClay



SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

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Director

U. S. Department of Agriculture - Forest Service

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GROWTH, MORTALITY, AND REGENERATION AFTER CUTTING IN LOBLOLLY PINE PULPWOOD STANDS

by

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INTRODUCTION

The age at which even-aged stands of loblolly pine start to show a decrease in cordwood growth rate depends primarily on site and density of stocking. For the majority of pine pulpwood stands in the mid-Atlantic coastal region, MacKinney and Chaiken (4) show that culmination of mean annual increment occurs between 30 and 40 years of age. It will occur earliest in high-density stands on good sites. In a study comparing the growth between thinned and unthinned loblolly pine stands in central Louisiana, Mann (5) reports that the greatest periodic annual cordwood growth occurred in unthinned stands up to age 33 on an average site index 93. After that age, heavy mortality in the merchantable size classes reduced the growth below that of the thinned stands. Although considerations such as product objective, early thinnings at a net profit, or logging cost as affected by tree size may influence the decision, it appears that when a stand approaches about 30 years of age, it would be advisable to make plans for some type of cutting to salvage expected mortality and to stimulate the growth rate.

METHODS OF CUTTING

In 1939, five blocks of six 0.4-acre plots each were located throughout the range of loblolly pine in Virginia and the Carolinas. The objective was to test the effects of six different methods of cutting in even-aged stands of pine pulpwood when (1) cutting pulpwood as a short-rotation final crop and, (2) cutting pulpwood as an intermediate crop in a long rotation aimed at the ultimate production of sawtimber, poles, and piling.

The short-rotation cutting methods were:

1. Seed-tree cutting removing all trees 5.0 inches d.b.h. and larger except four seed trees 9.0 inches d.b.h. and larger per acre. At the time of study establishment, the minimum diameter of a seed tree was considered to be 10.0 inches d.b.h. in Virginia and North Carolina, and 8.0 inches d.b.h. in South Carolina.

2. Seed-tree cutting removing all trees 5.0 inches d.b.h. and larger except 12 seed trees 9.0 inches d.b.h. or larger per acre.

3. Two cut shelterwood (6) removing all trees 5.0 inches d.b.h. and larger except 40 trees per acre of the best dominants and codominants after the first cut.

The long-rotation cutting methods were:

4. Diameter-limit cut removing all trees 7.0 inches d.b.h. and larger.

5. Moderate thinning from below leaving about 160 of the best trees per acre.

6. Heavy thinning from below leaving about 100 of the best trees per acre.

The averages for each treatment showed a volume before cutting of 25 to 35 cords per acre, an age of 25 to 30 years and a site index (average height of dominant and codominant trees at 50 years) of 75 to 85 feet. Two plots were well out of this range and were not included in the analysis. The last remeasurement of all plots was made in the winter of 1947-48, or 9 years after the initial cut. There were no stand improvement measures applied during this period.

Good forest management policy today would not accept the rather crude short-rotation cutting methods as practiced in this early study. New methods of seed-tree selection and stimulation, seedbed preparation, and control of inferior understory species are some of the techniques considered advisable to secure satisfactory regeneration. However, there are large acreages of loblolly pine stands not under intensive management which are still being cut by some of the methods practiced in this study. The records of growth, mortality, and regeneration during the 9-year period following cutting by the six methods tested provide some useful information regarding these stands.

GROWTH AND MORTALITY

A treatment comparison of average growth of the residual merchantable stand, ingrowth of new trees, and mortality during the 9-year period following cutting is shown in table 1. Representative conditions on diameter-limit

Table 1.--Growth and mortality per-acre, following different methods of cutting

Method of cutting	Volume			Periodic annual--			Compounded growth rate	
	Cut	Left	9 Years later	Residual net growth	Ingrowth	Mortality	Residual stand	Residual plus ingrowth
	Cords	Cords	Cords	Cords	Cords	Cords	Percent	Percent
4 seed trees	27.6	1.3	3.5	.09	.15	0	5.5	11.5
12 seed trees	26.1	2.3	5.6	.20	.18	.01	6.6	10.7
Shelterwood	23.3	6.8	13.2	.62	.10	.01	6.9	7.7
Diameter limit	22.7	6.1	8.0	.24	.09	.12	3.4	4.5
Moderate thinning	10.0	13.9	22.1	.86	.11	.06	5.0	5.6
Heavy thinning	15.0	12.7	21.3	.88	.11	.03	5.5	6.1

and heavy-thinning plots before and after cutting and 9 years later are shown in figures 1 and 2.

Volume growth in cords of the residual stand was greatest following the thinning treatments, where it averaged almost 0.9 cords per acre per year. The shelterwood produced a growth of about 0.6 cords, while the seed-tree and diameter-limit cuts had only 0.1 or 0.2 cords annual growth increase. These growth rates bear a strong relationship to the residual volumes left per acre in all cases except the diameter-limit cut. Under this treatment, the merchantable volume left was in the 5- and 6-inch diameter classes, consisting mainly of trees which were suppressed in the original stand; all the other cutting methods left a residual stand composed mainly of former dominants and codominants.

All cutting methods left small-crowned, low-vigor trees below 5.0 inches d.b.h. The ingrowth from this group into merchantable size was influenced greatly by degree of release. The seed-tree cuts, which gave the most release, resulted in an ingrowth some 50 to 75 percent greater than under the other cutting methods. Although the diameter-limit cut removed all competition by the larger trees, 195 trees per acre were left in the 5- and 6-inch diameter classes to compete directly with trees smaller than 5.0 inches.

BEFORE

AFTER

NINE YEARS

Figure 1.--This 25-year-old pine stand near Jarratt, Va., was cut to a 7.0-inch minimum diameter limit. Trees with number and band represent the 5- and 6-inch d.b.h. residual stand. All other merchantable trees were cut. This method of cutting appears least favorable.

CUTTING

CUTTING

AFTER CUTTING

Figure 2.--A 27-year-old pine stand given a heavy thinning where all merchantable trees except 100 of the best dominants and codominants per acre were cut. Trees with number and band represent residual stand. This method of cutting produced the best volume growth and gross returns. Plot located near Jarratt, Va.

Mortality was almost nonexistent following the seed-tree and shelterwood cuttings, where there were no suppressed residuals of merchantable size with small crowns left. An increase in the number of poor-vigor trees left brought about a corresponding increase in mortality. The moderate thinning left more of these trees than the heavy thinning, and the mortality rate was doubled. The residual stand left after the diameter-limit cut was composed almost entirely of trees which had been suppressed in the original stand, and here the mortality rate was greatest. It amounted to a loss of 0.12 cords per acre per year, or about 18 percent of the merchantable volume left after cutting. Chaiken (3) has reported a similar high mortality among poor-vigor trees left after partially cutting a stand of loblolly pine sawtimber. He states it would be well to anticipate this mortality and to remove such trees, in addition to those with severe logging injuries, at the time of cutting. It would appear that consideration should also be given to removing this class of tree in pulpwood stands, if it can be done economically.

When growth is considered as a compounded interest rate, the residual volume left by the shelterwood cut shows the highest growth rate with 6.9 percent. The 12-seed-tree cut produced 6.6 percent; the heavy thinning and four-seed-tree cut each had 5.5 percent; the moderate thinning had 5.0 percent; and the diameter-limit cut had a growth percent of only 3.4 percent. The high ingrowth relative to residual stand net growth, jumped the growth percent of the seed-tree cuts to about 11 percent, but the rates by the other cutting methods increased only slightly. Mortality is not included in the growth percents since it would be uneconomical to attempt to harvest these small volumes.

Leaving a low residual volume just to get a higher growth percent is not necessarily the best choice. To take an extreme example, leaving 2 cords per acre by a seed-tree method would produce about 1/3 cord per acre per year. In order to get the same annual volume of wood as that produced by the thinning methods (1.0 cord) would necessitate holding three times the acreage. The investment in wood volume by the seed-tree method (6 cords) would be about half that by the thinning methods (13 cords), but the investment in land and taxes would be three times as much while at the same time other costs such as road building and maintenance, fire protection, cruising, etc. would also be increased. Clearly then, a relatively high growth percent is not a final criterion by which to judge the desirability of a particular method of cutting.

FINANCIAL COMPARISONS

The techniques of comparative valuation provide a better measure of the relative financial returns associated with each method of cutting. This is simply computing the present worth (1939) of a given stand by adding the discounted value of the stand 9 years after applying a particular method of cutting to the value of the volume removed at time of cutting. Constant stumpage prices and discount rates are applied in the analysis to all methods of cutting. Since they apply equally to the volumes produced by any method,

and since we are seeking only to make a comparative rather than actual valuation, any price or rate will suffice. Those used here are $4.00 per standard rough cord, $30.00 per thousand board feet (Int. 1/4-inch rule), and a discount rate of 3 percent.

Thus, we assume an even-aged stand of pulpwood-size pine containing 25 cords per acre. Which of the six methods of cutting will produce the highest present worth? The present worth of this 25-cord stand before cutting is $100 per acre (25 x $4.00 per cord). The percent of total volume cut by each method can be computed from table 1. It ranges from 96 percent when leaving four seed trees to 42 percent when making a moderate thinning. The volume removed in each method of cutting is valued as pulpwood at $4 per cord. The future stand may in some cases, however, have grown to a point where there is an operable amount of sawtimber volume in trees 10.0 inches d.b.h. and larger. Nine years after cutting, then, the stand may have sawtimber values in combination with pulpwood values. Or, if utilization policy requires it, the entire stand of trees regardless of size may be valued as pulpwood only.

The present worth resulting from each method of cutting when (1) all volumes are considered as pulpwood, and (2) the stand 9 years hence is valued as sawtimber and pulpwood combined, is shown in table 2.

The differences in present worth between treatments are not very large when all volumes are cut and valued as pulpwood. The greatest present worth ($117 per acre) results from the heavy thinning; the shelterwood cut and moderate thinning are slightly less with $114 and $113, respectively. There is a further decrease when cutting to 12 or 4 seed trees, where the respective present worth is $109 and $106. Diameter-limit cutting is lowest with $104 per acre.

Even though the values of the original cuts leaving seed trees were almost double the values removed in the thinning operations, the growth of the residual stands left after thinning more than made up this initial difference. The annual growth in cords for the diameter-limit method was almost equal to that for the 12-seed-tree method, but the present worth was reduced by the lower value of the initial cut. Other considerations such as a discount rate other than 3 percent, market trends, logging costs as affected by tree size, regeneration problems, or a combination of these factors, may easily alter the differences when all trees are cut and valued as pulpwood.

In 1948 all stands except those cut to a minimum 7.0 inches d.b.h. had an operable volume for a sawtimber cut, the lowest volume being some 1,000 board feet per acre on the areas cut to four seed trees. When the future stands are valued as sawtimber for trees 10 inches d.b.h. and larger and as pulpwood for trees 5- to 9-inches d.b.h., a pronounced difference appears in present worth by the various cutting methods. The shelterwood and thinning methods now show a definite superiority over the seed-tree or diameter-limit cutting methods. The heavy thinning produces a present worth of $231 per acre, while the four-seed-tree and 12-seed-tree methods show a value of $121 and $138 per acre, respectively. The moderate thinning and shelterwood are $192 and $199, respectively, while the diameter-limit method has a present worth of only $104 per acre. The latter method

Table 2.--Comparative value and present worth per acre after cutting by different methods

Method of cutting	Stand 9 years after cutting				Value of 1939 cut	Present worth (1939)	
	Valued[1] as--		Discounted[2] as--				
	Pulpwood	Sawtimber and pulpwood	Pulpwood	Sawtimber and pulpwood		Pulpwood	Sawtimber and pulpwood
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
4 seed trees	13	33	10	25	96	106	121
12 seed trees	22	60	17	46	92	109	138
Shelterwood	48	159	37	122	77	114	199
Diameter limit	33	33	25	25	79	104	104
Moderate thinning	93	196	71	150	42	113	192
Heavy thinning	82	231	63	177	54	117	231

1/ Pulpwood stumpage $4.00 per standard rough cord. Sawtimber stumpage $30.00 per thousand board feet (Int. 1/4-inch rule). All figures rounded off to the nearest dollar.

2/ Discount rate 3 percent.

was low because it produced no trees of sawtimber size in the 9 years following cutting. The shelterwood and thinning methods had high present worth because the residual stand was composed primarily of select dominant and codominant trees. The seed-tree cuttings did not provide enough trees to produce an appreciable amount of sawtimber volume growth. A discount rate as high as 9 percent does not change the relative position of the present worths, although it does lessen the range of differences.

Table 2 also shows that when the stand is given a shelterwood cut, moderate thinning, or heavy thinning, a gross return of $236, $238, and $285 per acre, respectively, is earned in 34 to 39 years. This may be compared to clear cutting 25 cords per acre on a short rotation of about 25 to 30 years for a gross return of $100 per acre at $4.00 per cord. The rotation period will vary by site and density of stocking. Thus, by making a partial cut and carrying a thrifty residual stand to sawtimber size, it appears possible for one who sells stumpage at the quoted prices to realize in 34 to 39 years a gross return greater than that produced by two short-rotation clear cuttings in a period of about 50 to 60 years.

Financial comparisons between cutting methods based on data for a complete rotation would be highly desirable. The results obtained here are taken from records over a 9-year period following the initial cut and may not necessarily remain the same over a longer period. The possibility of later ingrowth into pulpwood or sawtimber classes, or the effect of additional cuttings in the thinned stands may tend to alter the value differences between cutting methods. It is difficult to find all the answers in a single study, but fitting together the results of many studies may offer a solution.

REGENERATION

Recent research findings have assisted owners in getting prompt and adequate loblolly pine regeneration.

Pomeroy (7) discusses the selection of good seed trees and the frequency of seed production, season of dispersal, and distribution. He suggests that seed trees should have large, dominant crowns with a past record of fruitfulness as indicated by the presence of many old cones. Trees 11 inches d.b.h. or smaller cannot be depended on as good seed trees. Occurrence of good seed years, season of logging, control of understory competition, and seedbed preparation are also important factors in aiding regeneration.

Trousdell (8) points out that logging slash provides a very poor seedbed, requiring 83 seeds per established seedling as compared to 29 seeds on undisturbed surfaces, 12 seeds on a logged and burned surface, and only 7 seeds on a disked and logged surface. Logging a stand leaves a seedbed pattern composed of slash, exposed mineral soil, and undisturbed areas. When logging is done with light equipment and heavy slash is left on the ground, it is apparent that a very large amount of seed would be needed to establish a new stand.

Even with an adequate seedfall on a suitable seedbed, the survival and growth of established pine seedlings can be seriously retarded by a dense understory of hardwoods. Chaiken (1, 2) discusses this problem and offers several means by which it may be overcome.

But none of these management techniques was being practiced in 1939. Seed trees were selected according to the standards of the time and although some of the seed trees were larger than 11 inches d.b.h. and showed evidence of being good seed producers, many of them were below this diameter and had no cones. This was particularly true in the shelterwood cutting, and to some extent in the 12-seed-tree cutting, where it was difficult to find a full quota of trees of proven seed-producing capacity. Truck roads were held to a minimum on the plots, slash was left undisturbed, and no measures were taken to improve seedbed conditions (figures 3 and 4). Three years after cutting there was an average of some 2,000 hardwood stems per acre on the seed-tree, shelterwood, and diameter-limit areas (table 3). By 1948 this had increased to from 3400 to 4900 stems per acre. No steps were taken to reduce this competition.

Table 3.--Number of hardwood stems per acre

Method of cutting	Size class	Stems per acre			
		1939	1942	1945	1948
		Number	Number	Number	Number
4 seed trees	under 4.5 ft.1/	--	1300	2215	3040
	over 4.5 ft.2/	420	755	842	1132
12 seed trees	under 4.5 ft.	--	1080	1340	3915
	over 4.5 ft.	342	607	777	978
Shelterwood	under 4.5 ft.	--	1095	1185	2245
	over 4.5 ft.	510	855	1010	1137
Diameter limit	under 4.5 ft.	--	1750	2355	2265
	over 4.5 ft.	387	818	907	1260

1/ Based on a 10-percent sample.
2/ Based on a 100-percent sample.

Under the circumstances, it is not surprising that a satisfactory new stand has failed to develop. Following cutting, all pine seedlings under 4.5 feet in height were eradicated on one-half the area of each plot cut by seed-tree, shelterwood and diameter-limit methods, regeneration not being an immediate problem on the thinned plots. The purpose was to obtain an estimate of seedlings produced exclusive of advanced reproduction. A 10-percent sample was made of all pine seedlings under 4.5 feet on both the eradicated and non-eradicated portions of the plots in 1942,

Figure 3.--One year after cutting a 27-year-old pine stand to 12 seed trees per acre (numbered trees). Hardwoods are infrequent and seedbed is still satisfactory, but seed trees averaged about 10 inches d.b.h. and none of them had old cones as evidence of seed-producing ability. By 1948 an adequate stand of reproduction had still failed to develop. Preharvest release of cone-bearing seed trees would have greatly increased the likelihood of success on this area.

Figure 4.--A 25-year-old pine stand one year after cutting to 12 seed trees per acre (some barely distinguishable in background) showing immediate problem created by understory hardwoods. Most of the seed trees on this plot bore cones at time of cut and by 1948 there were some 1500 pine stems per acre in the 0.6- to 4.5-foot height class. All of them, however, are overtopped by hardwoods. Elimination of competing species is essential for establishment of a succeeding pine stand.

1945 and 1948. An estimate of the number of established seedlings per acre, excluding those under 6 inches in height, by year and cutting method for the eradicated portions of the plots is shown in table 4.

Table 4.--Estimated pine reproduction under 4.5 feet in height[1/]

Method of cutting	Total seedlings per acre[2/]				Free seedlings per acre[3/] 1948
	1939	1942	1945	1948	
	Number	Number	Number	Number	Number
4 seed trees	0	260	980	1980	740
12 seed trees	0	360	760	2340	680
Shelterwood	0	250	1000	2370	370
Diameter limit	0	140	430	620	210

1/ Excluding reproduction under 6 inches in height.
2/ Based on 10-percent sample.
3/ Free of direct overhead shade.

Since the estimate is based upon a 10-percent sample not too much reliance can be placed on the actual figures, but even with a large error of estimate, it is evident that none of the cutting methods has produced an adequate crop of free-growing seedlings within a reasonable time. Side seeding from adjacent uncut stands has undoubtedly swelled the seedling count on many of the plots as evidenced by the seedlings on the areas cut to a 7.0-inch diameter limit. Some of the seedlings on the diameter-limit plots may have come from residuals which had developed an early seed-producing ability, although there are no data available to support this notion. An estimate of seedlings per acre on the non-eradicated portion of the plots shows that these portions had no more seedlings by 1948 than the eradicated portions, even though they had some at the start.

An interesting point is the steady increase in number of seedlings per acre over the 9-year period, in spite of the increasing hardwood competition as shown in table 3. More seed is being put down as the pine overstory trees become more mature, bumper seed crops occur, and some of the older seedlings manage to hang on or to find their way up through an opening. If one could accept a 6- to 9-year waiting period, stem-wise release of the established pine reproduction might provide the beginning of a new stand.

Of course, there are many pine pulpwood stands with relatively few hardwoods in the understory. Such stands cut by a seed-tree or shelterwood method may eventually develop a stand of pine reproduction without assistance. Although an unmanaged forest may thus produce a succeeding pine crop, it would be a risky venture involving an unnecessary time lag on lands acquired for the growing of timber.

A 100-percent tally of all pine over 4.5 feet high made after cutting and again in 1942, 1945 and 1948, further reveals the inadequacy of early stand development following cutting by seed-tree, shelterwood, or diameter-limit methods. The number of pine trees per acre by diameter group, year and cutting method is shown in table 5.

Table 5.--Pines per acre over 4.5 feet high, by method of cutting, diameter group, and year

Method of cutting	D.b.h. group	Total trees per acre[1]				Free-growing trees per acre[2] 1948
		After cut, 1939	1942	1945	1948	
	Inches	Number	Number	Number	Number	Number
4 seed trees	0-1.9	10	8	188	380	239
	2.0-4.9	120	75	50	70	52
	5.0-9.9	0	15	32	38	35
	10.0 +	5	5	5	5	5
12 seed trees	0-1.9	30	25	172	365	197
	2.0-4.9	115	65	40	75	59
	5.0-9.9	1	15	35	48	45
	10.0 +	11	12	12	10	10
Shelterwood	0-1.9	48	28	72	192	90
	2.0-4.9	105	70	55	58	31
	5.0-9.9	22	22	28	30	23
	10.0 +	22	32	40	45	45
Diameter limit	0-1.9	55	40	52	60	28
	2.0-4.9	168	110	72	80	38
	5.0-9.9	195	190	195	185	172
	10.0 +	0	0	0	0	--

1/ Based on a 100-percent sample.
2/ Free of direct overhead shade.

If adequate reproduction had become established following cutting, and normal growth ensued, one might look for a substantial number of trees in the 0- to 1.9-inch diameter group by 1948. Yet this diameter group shows a deficiency for each cutting method. All residual stands had a decrease in the number of trees between 4.5 feet in height and 5.0 inches d.b.h. following cutting. It was not until 1945 (6 years after cutting) that the seed-tree stands made up this loss. In 1948 (9 years after cutting) the shelterwood stands made it up. And the stands cut to a 7.0-inch diameter limit still had fewer trees under 5.0 inches d.b.h. in 1948 than in 1939. The net

loss can be attributed to mortality due to logging damage and poor vigor, and to growth into larger diameter classes. The delay in recruitment from smaller size groups is directly associated with the delay in establishment of reproduction, as shown in table 4.

SUMMARY

On the basis of data collected over a 9-year period from a series of 0.4-acre plots located in loblolly pine pulpwood stands of Virginia and the Carolinas, heavy thinning from below has produced greater returns during the decade after cutting than has moderate thinning from below, cutting to 4 or 12 seed trees, shelterwood, or cutting to a 7.0-inch diameter limit. The shelterwood cutting showed the next best return, followed by moderate thinning from below, 12 seed trees, four seed trees, and diameter limit. Regeneration cuttings (seed tree and shelterwood) in these 25- to 30-year-old stands have failed to reproduce an adequate stand of pine within a reasonable time. Recent research findings pertaining to preharvest seed-tree release, seedbed preparation, and hardwood control offer a means by which this problem may be overcome under intensive management. Cutting to a 7.0-inch minimum diameter limit is the least favorable of all methods tested, because of a relatively high mortality and low growth rate.

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Soil Temperatures in the South Carolina Piedmont

by

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SOIL TEMPERATURES IN THE SOUTH CAROLINA PIEDMONT

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Geoffrey E. Greene

INTRODUCTION

This paper reports temperatures in the upper 6 feet of soil under four conditions of plant cover in the South Carolina Piedmont. Such information has not been reported previously.

The temperature of the soil is important because it is one of the limiting factors to root growth. Plant growth has been found to be accelerated within certain ranges of soil temperature and inhibited or prevented beyond such boundaries. Consequently, knowledge of soil temperature may be useful in determining suitability of planting sites, length of growing season, and periods of most rapid growth.

Temperature information was obtained from an installation of fiberglas electrodes used in the determination of soil moisture by the electrical resistance method. The fiberglas units contained thermistors for temperature measurements and were buried beneath barren, grass, and forested sites.

Observations were made at the Calhoun Experimental Forest located 7 miles southwest of Union, South Carolina. Monthly average soil temperatures were derived from daily observations taken during the period September 1950 through October 1951.

Soil temperatures have been studied extensively in Europe and in this country. Geiger (5) refers to most of the European studies in his treatise on microclimate. In this country, many of the studies of soil temperature have been made in the West in connection with frost damage to orchards (9, 8). From the engineering aspect, Crawford (4) has summarized what he believes to be the most important publications in English on the subject. For the influence of forest cover on the temperature of the soil, the reader is referred to Kittredge (7). More recently, Hursh (6) has reported temperature information for the upper 6 inches of soil under hardwood forest, grass, and barren conditions in the Copper Basin of Tennessee.

CLIMATE AND SITE DESCRIPTIONS

Climate of the South Carolina Piedmont is humid, with relatively mild winters and hot summers. In the vicinity of Union, the growing season has an average length of 208 days. The average date of the last killing frost in the spring is April 5 and the first in the fall is October 30. Mean precipitation is 47.61 inches. Rainfall distribution is fairly uniform throughout the year. An index to local meteorological conditions for the period of soil temperature measurement is given by the summary of climatological data in table 1. The data were obtained from a weather station at the experimental forest headquarters. All the soil temperature measurements were made less than 3 miles from this station. Table 1 gives mean daily maximum and minimum air temperatures by months for the period August 1950 through October 1951. Also in table 1 are monthly departures of temperature and precipitation from the 59-year average values for Santuck, South Carolina, which is 11 miles east of the study area.

Air temperatures were highest in August with a mean of 80.3°F., and were lowest in December with a mean of 38.4 degrees. It will be noticed that air temperatures during the 15-month period were generally lower than the 59-year average. Monthly precipitation was deficient in all but 3 months and there was a total deficit of 19.41 inches for the period (table 1).

The sites where soil temperatures were measured are located on nearly level ridge top or upper slope positions on soils of the Cataula and Lloyd series. These soils are derived from granites, gneisses, and schists and are characterized by red-clay B horizons 4 to 6 feet thick. Individual characteristics of the four areas reported are described below, and their locations with respect to one another are illustrated in figure 1.

Shortleaf pine-hardwood (Plot A).--The area representing older forest growth was formerly agricultural land but has not been cultivated for at least 50 years and is only moderately eroded. It faces northwest on a slope of about 8 percent. The soil is a Cataula sandy loam with horizons comparable to those at the loblolly pine plantation except that a humus layer is present. Vegetation consists of 40 to 50-year-old shortleaf pine (P. echinata, L.) with an understory of hardwoods composed principally of dogwood (Cornus florida) and hickory (Hicoria spp.). The shortleaf pines average 5.8 inches d.b.h. and heights range up to 50 feet. Most of the hardwoods are less than 2.5 inches in diameter. Of the trees 4 inches and larger in diameter, there are 520 per acre with a basal area of 141 square feet. The forest floor is from 2 to 3 inches thick. Temperature measurements were made within the stand about 100 feet from an unsurfaced road (fig. 1).

Loblolly pine plantation (Plot B).--This site is situated on the upper portion of a broad ridge that slopes about 3 percent to the southeast. It was last cultivated in 1940. The soil is a Cataula sandy loam. The topsoil has no humus layer and is about 5 to 7 inches deep. It lies

Table 1.--Mean daily maximum and minimum air temperatures by months, and total monthly precipitation at the Calhoun Experimental Forest from August 1950 through October 1951.

Year and month	Temperature				Precipitation	
	Max.	Min.	Mean	Mean departure 1/	Total	Departure 1/
	Degrees F.				Inches	Inches
1950						
August	89.7	63.6	76.7	-1.6	3.10	-2.69
September	81.2	58.1	69.7	-4.0	3.07	-0.37
October	77.0	51.4	64.2	2.1	3.92	0.88
November	62.2	31.7	46.9	-4.3	0.82	-1.83
December	50.0	26.9	38.4	-5.3	3.04	-1.21
1951						
January	56.0	30.2	43.1	-0.2	1.86	-1.94
February	57.8	29.7	43.8	-0.6	2.23	-2.21
March	63.3	39.6	51.5	-0.9	4.32	-0.06
April	71.9	45.1	58.5	-1.8	2.35	-1.12
May	83.9	50.1	67.0	-2.4	0.77	-2.59
June	89.7	63.4	76.5	-0.3	4.84	1.03
July	92.6	65.4	79.0	-0.4	3.65	-1.53
August	94.2	66.4	80.3	2.0	0.89	-4.90
September	85.5	60.6	73.0	-0.7	4.67	1.23
October	77.2	50.6	63.9	1.8	0.94	-2.10
Total					40.47	-19.41

1/ Difference between measurements taken at the experimental forest headquarters and the 59-year average at the U. S. Weather Bureau cooperative station at Santuck, South Carolina.

over a clay B horizon that extends to 4 feet. The C horizon begins at 4 feet and is made up of decomposed gneiss or granite. Loblolly pines were planted early in 1941. In September 1950, they averaged 5.3 inches d.b.h. and 31.1 feet high with a crown density of about 58 percent. There were 760 trees per acre with a basal area of 103 square feet. The forest floor, composed of weathered pine needles, was 2 inches deep and weighed approximately 13,000 pounds per acre.1/ Soil temperatures were measured at a point well within the stand about 130 feet from the nearest opening.

1/ Based on oven-dry weight.

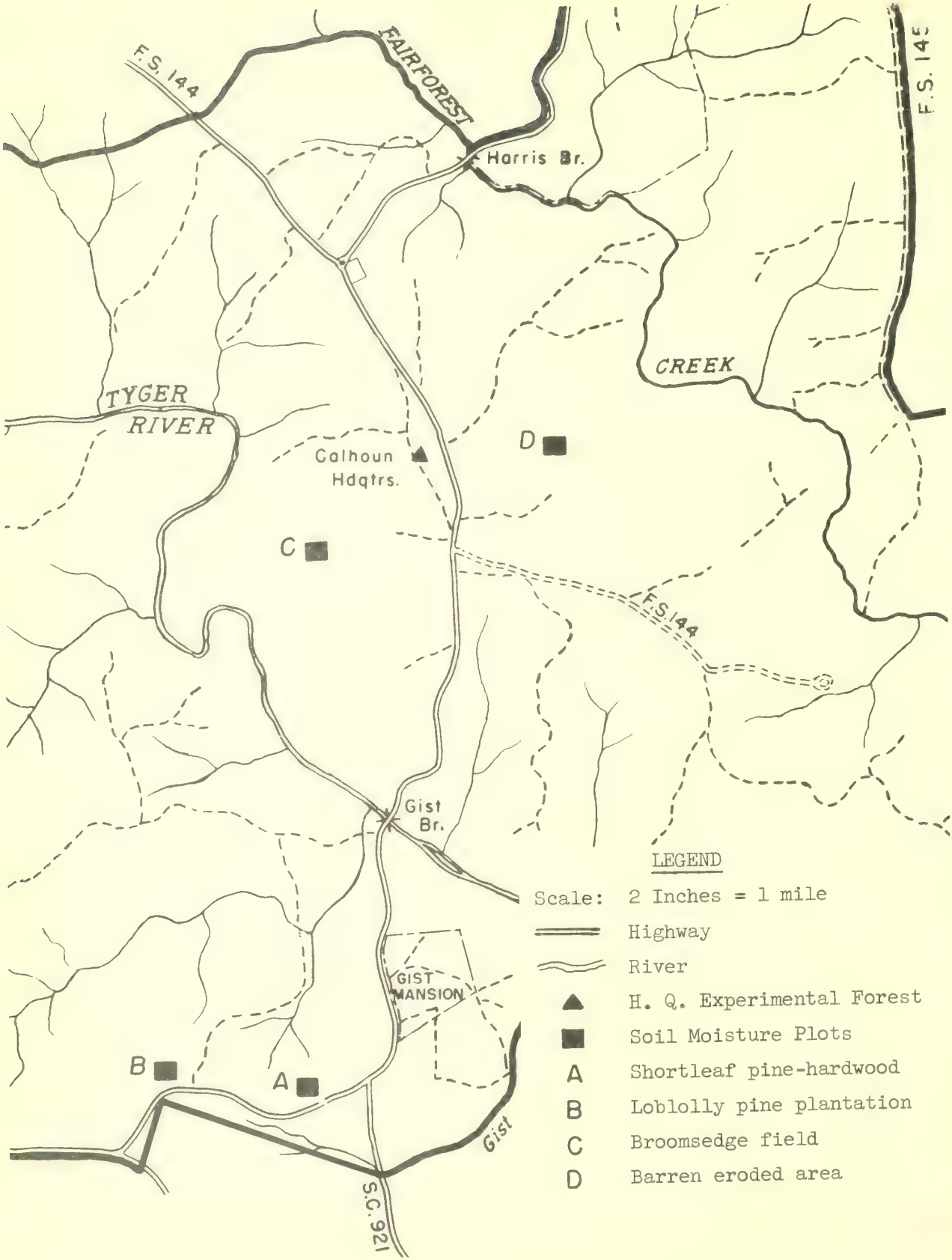

Figure 1.--Location of soil moisture plots on the Calhoun Experimental Forest, where soil temperature information was obtained.

Broomsedge field (Plot C).--This site is an old field situated on a ridge top that slopes about 3 percent southward. It was last cultivated in 1942. The soil is a Lloyd loam. Topsoil is present in the form of a brown loam about 6 inches deep. The subsoil is a stiff clay that extends from 6 to 72 inches. It is less compact and more permeable than are soils of the Cataula series. Vegetation is predominately broomsedge with a cover density of 95 to 100 percent. It has been maintained in that cover type by periodic removal of invading pines.

Barren site (Plot D).--This area is a relatively level portion of an old field situated on a ridge top that rises steeply on the north side. It was last cultivated in 1930. The soil has been severely eroded and the original sandy loam surface-horizon of the Cataula series has been completely removed. The upper 28 inches of this type of clay has an angular blocky structure. Below 28 inches, mica particles and quartz fragments are abundant, and the soil has a platy structure. The fiberglas elements were installed in a fully exposed barren portion of the area. At a distance of 6 feet there are scattered clumps of broomsedge (Andropogon spp.), and at a distance of 40-feet there is abundant loblolly pine (P. taeda, L.) regeneration.

METHODS

Fiberglas electrodes (3) were installed within 25 by 25-foot fenced enclosures at each site. The electrodes were inserted at depths of 2, 12, 18, 24, 36, 48, 60, and 72 inches along the side of a 5-inch auger hole. The excavated soil was repacked into the hole to duplicate thickness and arrangement of the original soil horizons. The thermistor[2/] in each electrode was used to measure temperature. The Colman (3) ohmmeter was used to measure thermistor resistance. The resistance readings were converted to temperature in degrees Fahrenheit from graphs compiled by Colman. Thermistors of the type contained in the fiberglas units are capable of registering small temperature changes. However, with the ohmmeter used, temperature determinations are believed to be accurate to only $\pm$ 1°F. Measurements were made daily between 8:00 and 9:00 a.m. Because of the distance between plots (fig. 1), there was a time interval of approximately 40 minutes between the first observation at Plot D and the last at Plot B. This time interval was consistent from day to day and probably had no influence on comparisons of temperature between vegetated sites. It probably did affect comparisons between the barren and vegetated sites, since the barren area was read earlier in the morning before surface temperatures were materially influenced by bright sunlight.

RESULTS

The presence of vegetation had its greatest effect on soil temperatures in summer, and temperatures were progressively cooler from barren to high forest conditions. Monthly average temperatures from September 1950 through October 1951 are given in table 2 for the upper 6 feet of soil

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2/ Western Electric No. 7A.

under the four cover conditions. Annual minimum soil temperatures occurred from one to two months later than minimum air temperatures (table 1). Under forest vegetation for example, the entire 6 feet of soil was coldest in February (table 2A and B). At the grass and barren areas the temperatures in the upper 18 inches of soil reached a minimum in January and in the remainder of the 6-foot profile they were lowest in February (table 2C and D). For barren conditions, January temperatures averaged 40° at 2 inches depth and 43° at one foot. At comparable depths under vegetation the soil was warmer by approximately 3° and 1° respectively. In the zone from 2 to 6 feet the February temperature of the barren soil varied from 47° to 52°, which was generally 1° to 3° warmer than under grass or forest cover.

Except for the 2-inch depth at the barren area, the temperatures in the upper 4 feet of soil at all sites were generally highest in August, which was the time of the annual maximum air temperature. On the forested sites, the soil reached its maximum temperature at 5 feet during September and 6 feet in October, 1951. The soil at the barren site and broomsedge field reached its maximum at 5 and 6 feet in September. In table 2 it will be noted that the annual maximums at 6 feet may not occur at the same time each year. For 1950, they did not occur at any of the sites in October. At a depth of 18 inches, the soil temperatures in August averaged approximately 82° at the barren site, 77° at the broomsedge field, 74° at the loblolly pine plantation, and 71° at the pine-hardwood stand. Even at a depth of 6 feet there was an appreciable influence of vegetation on soil temperatures. In September 1951, for example, the temperature at a depth of 6 feet was 75° at the barren area and 67° under the older forest.

Table 2D shows that the 2-inch depth at the barren area reached an annual maximum in July rather than August. Because of greater day lengths and more intense solar radiation in July, the absence of shading vegetation would have the most noticeable effect on soil temperatures. Consequently, it was believed that the soil at 2 inches depth at the barren area tended to heat more before the time of observation than it did at the vegetated sites.

Although the annual extremes occurred at a later date with increasing depth, the differences between successive months were relatively small. Therefore, for most purposes of comparison, the temperatures throughout the upper 6 feet of soil can be considered to have reached a minimum in February and a maximum in August. Average temperatures by depth at three sites for February and four sites for August are plotted in figure 2. Mean air temperatures for the two months are indicated by vertical lines. Since there was no appreciable difference in the annual minimums between the two forested areas, only temperatures for the pine-hardwood stand are plotted for February in figure 2. Compared to mean air temperature for February, the soil averaged approximately 3° colder near the surface but at a depth of 6 feet it was from 6° to 9° warmer. Temperature profiles of the soils for August illustrate the influence of vegetation on soil temperatures in summer. It will be noted that the soil temperature differences between the loblolly pine plantation and the broomsedge field were appreciable down to a depth of about 3 feet. Below that depth however, the temperature differences under young forest and grass were relatively small. In August, the soil at a depth of 6 feet under vegetation was from 12° to 14° cooler than mean air temperature, while for barren conditions it was 6° cooler than mean monthly air temperature. At a depth of 12 to 30 inches the barren soil was as much as 2° warmer

Table 2.--Monthly average soil temperatures for selected depths from September 1950 through October 1951
(In degrees F.)

Depth (Inches)	1950 Sept.	Oct.	Nov.	Dec.	1951 Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.
UNDER A 40 TO 50-YEAR-OLD SHORTLEAF PINE-HARDWOOD STAND														
2	67.9	62.5	52.8	45.8	43.0	42.6	49.4	54.5	60.2	66.7	69.9	71.3	67.7	62.7
1/12	68.6	63.7	56.0	48.0	44.2	43.9	50.1	54.4	59.7	65.5	69.4	70.7	68.6	64.1
18	69.0	64.5	57.7	50.0	45.6	44.9	50.7	54.6	59.6	65.1	69.4	70.6	68.8	65.0
24	68.0	64.4	58.2	50.5	45.7	44.4	49.8	53.1	57.9	62.8	67.2	69.2	68.3	65.6
36	67.9	65.4	60.9	53.3	48.3	46.6	50.2	53.1	57.5	61.6	66.5	68.2	68.4	66.9
48	68.2	65.8	61.8	55.4	49.5	46.9	50.5	52.8	56.4	60.3	65.0	67.4	67.2	66.5
60	68.1	66.2	63.2	57.7	51.8	49.4	51.3	53.1	56.2	59.6	64.0	66.2	67.0	66.7
72	66.6	65.2	63.4	58.6	52.2	50.0	50.6	52.2	55.0	57.5	61.5	65.8	66.6	67.0
UNDER AN 11-YEAR-OLD LOBLOLLY PINE PLANTATION														
2	68.9	62.5	51.2	42.9	42.6	42.1	48.7	54.7	64.0	69.6	72.8	73.3	69.3	63.4
12	70.8	65.2	56.1	46.7	44.0	44.0	50.5	55.0	63.4	68.9	72.7	73.9	71.1	66.0
18	71.4	65.3	58.3	48.7	45.6	44.8	50.8	54.8	62.9	68.3	72.4	73.6	71.4	66.9
24	70.6	66.5	58.9	49.9	45.7	44.4	50.3	54.0	61.3	66.6	70.6	72.4	70.7	66.8
36	70.6	67.2	61.3	52.7	47.8	45.6	50.5	53.3	59.8	65.1	69.2	71.6	70.2	67.7
48	71.1	68.2	63.6	55.7	50.3	48.4	51.2	53.8	59.6	64.7	69.0	71.2	71.3	68.4
60	68.9	67.4	63.4	56.4	50.5	48.2	50.6	52.4	57.1	61.6	66.3	68.2	68.5	68.2
72	68.8	68.0	64.9	58.8	52.8	50.4	51.4	53.1	56.8	61.1	65.5	67.7	68.2	68.7
UNDER A BROOMSEDGE FIELD														
2	70.8	63.5	49.7	43.5	42.9	43.5	52.4	59.7	70.4	75.8	77.9	78.2	72.3	63.1
12	71.2	65.3	53.8	46.2	43.8	44.9	52.2	57.9	68.5	73.9	77.4	77.8	72.8	65.5
18	71.9	65.9	55.8	47.6	44.8	45.4	52.2	57.8	68.0	72.9	77.1	77.4	73.4	66.6
24	72.7	67.4	59.3	51.2	48.2	47.8	53.9	58.3	67.9	72.3	76.1	77.0	74.3	68.3
36	70.4	66.7	60.1	52.4	48.0	47.0	51.3	54.9	63.0	67.6	71.8	73.3	72.1	67.7
48	70.3	67.5	62.6	55.4	50.3	48.9	51.8	54.3	61.1	65.8	69.7	71.7	71.4	68.5
60	69.9	68.1	64.3	58.2	52.2	50.6	52.2	54.4	59.9	64.7	68.4	70.0	70.8	68.9
72	68.6	67.8	65.0	59.9	53.8	51.4	52.1	53.8	58.3	62.1	66.5	68.0	68.6	68.6
UNDER A BARREN ERODED AREA														
2	70.5	60.9	43.7	40.4	40.0	41.0	49.4	57.3	69.2	75.1	78.1	77.2	71.1	57.2
12	74.5	65.8	51.9	44.0	42.6	44.1	51.4	57.7	70.6	76.8	80.2	80.7	74.9	68.4
18	77.0	68.4	56.6	47.4	45.8	46.6	53.5	59.1	71.6	77.5	81.3	82.0	77.6	67.8
24	77.5	69.2	59.0	49.6	47.3	47.0	53.5	58.1	70.6	76.5	80.6	81.2	77.8	71.5
36	76.9	70.0	62.1	52.8	48.7	47.8	52.7	56.4	67.5	73.1	78.2	78.8	77.1	72.2
48	76.5	70.9	64.2	55.9	50.4	49.2	52.6	55.6	65.0	70.4	76.2	77.3	76.8	72.4
60	76.4	72.1	66.7	59.3	52.9	51.2	53.4	56.3	64.1	69.4	74.7	75.9	76.8	73.6
72	75.4	72.1	67.7	61.6	54.7	52.4	53.7	55.9	62.5	67.9	71.9	74.3	75.2	73.5

A, B, C, D

1/ Average of temperatures at 10 and 14 inches.

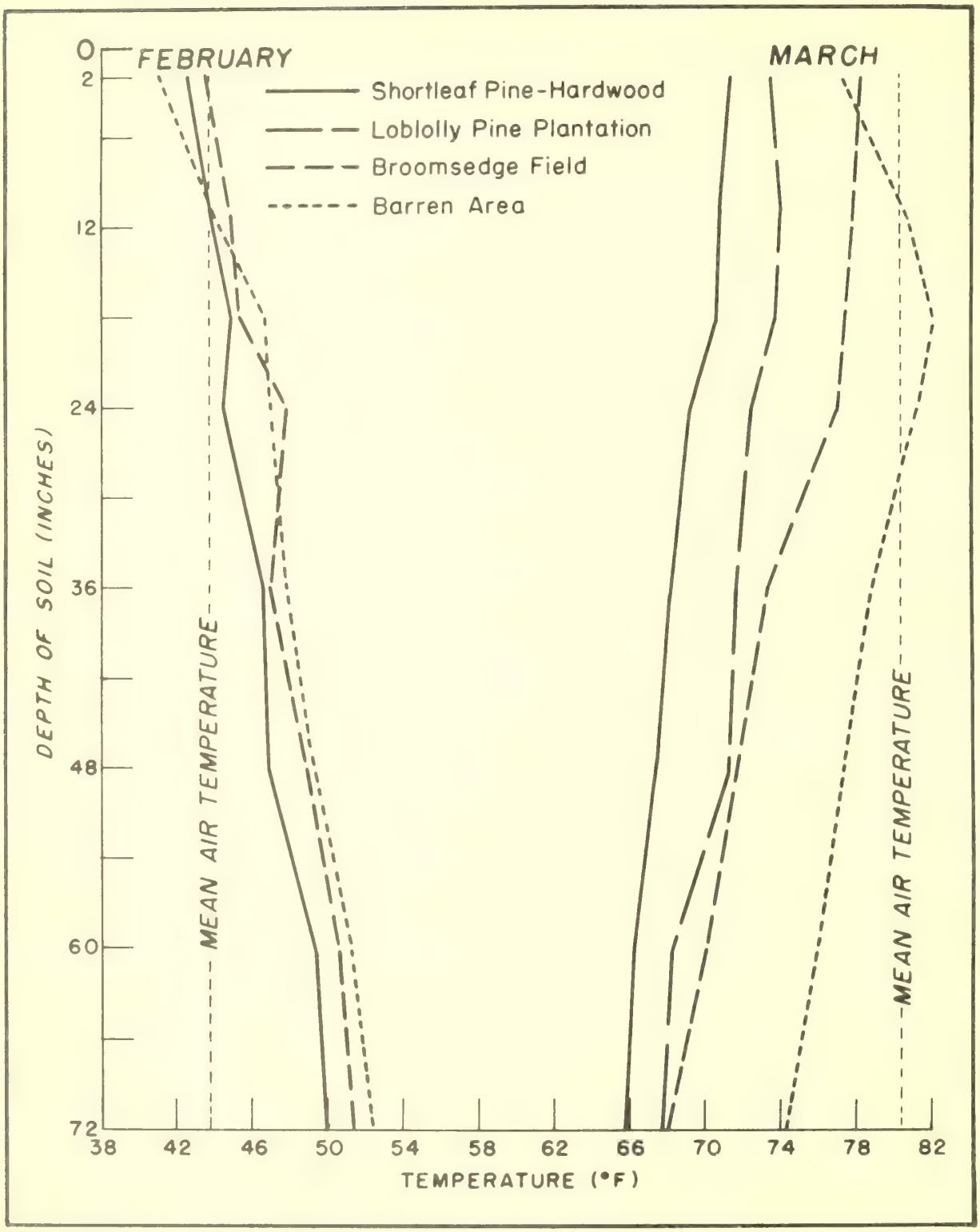

Figure 2.--Average temperature of the soil to a depth of 6 feet under a shortleaf pine-hardwood stand, a loblolly pine plantation, a broomsedge field, and a barren area, for February and August 1951. Mean air temperatures at a nearby weather station are indicated by the vertical lines.

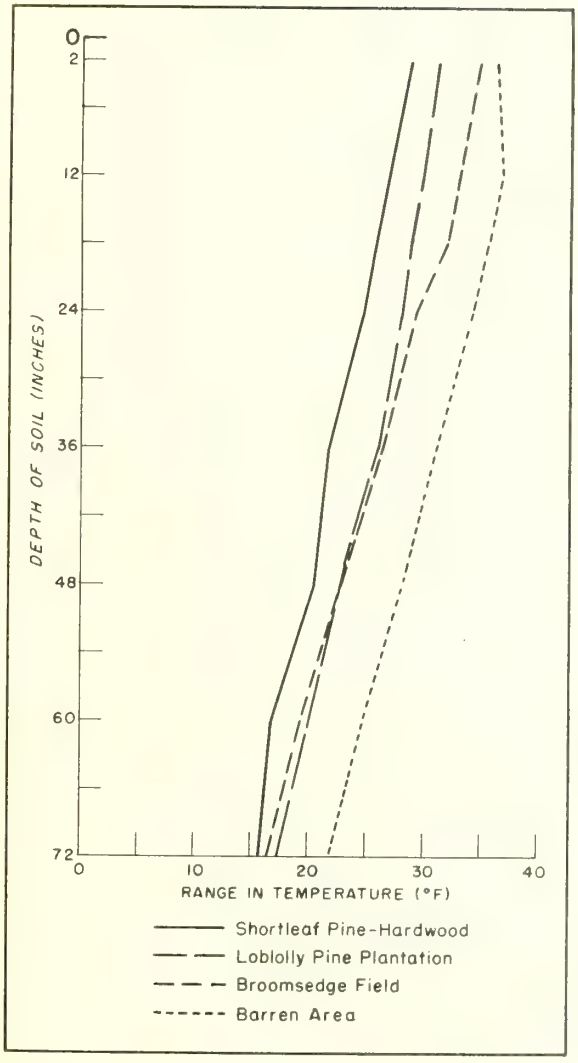

Figure 3.--Range in temperature between February and August 1951, by soil depths for each site.

than mean air temperature (fig. 2). In general, the temperature gradient throughout the upper 6 feet of soil at all sites tended to be linear with respect to depth, although in the upper 18 inches of barren soil there was a marked decrease in temperature with nearness to the surface. Unpublished data at this station, of hourly soil temperatures for a 24-hour period in summer, showed that the daily fluctuation was generally limited to about the upper 18 inches of soil. In addition, daily minimums in the 18-inch zone of barren areas tended to occur between 6:30 and 8:30 a.m. Consequently, the daily observations at the barren site were made when the soil was probably near its minimum temperature in the upper foot or so and would thus account for the lower temperatures upward from the 18- to 2-inch levels.

A comparison of the range of average soil temperatures between February and August is illustrated in figure 3. For barren conditions, the annual range in soil temperature was 36° at 2 inches depth and 22° at a depth of 6 feet. At the same depths under the pine-hardwoods, the temperature range was approximately 29° and 16° respectively. Under young pines and grass cover the yearly range of soil temperature was intermediate between the above values.

Warming Period

The effect of vegetation on soil temperatures was noticeable throughout the year. One effect, was smaller differences in soil temperature between successive months with increasing amounts of vegetation. Seasonal changes in temperature profiles are illustrated in figures 4 and 5 for the four cover conditions. Monthly average soil temperatures were plotted by depth for two periods: one in which the soil was warming (fig. 4) and the other when the soil was cooling (fig. 5). Soil heating began in

Figure 4.--Monthly average soil temperatures from February through August 1951, showing the seasonal heat gain throughout the upper 6 feet of soil.

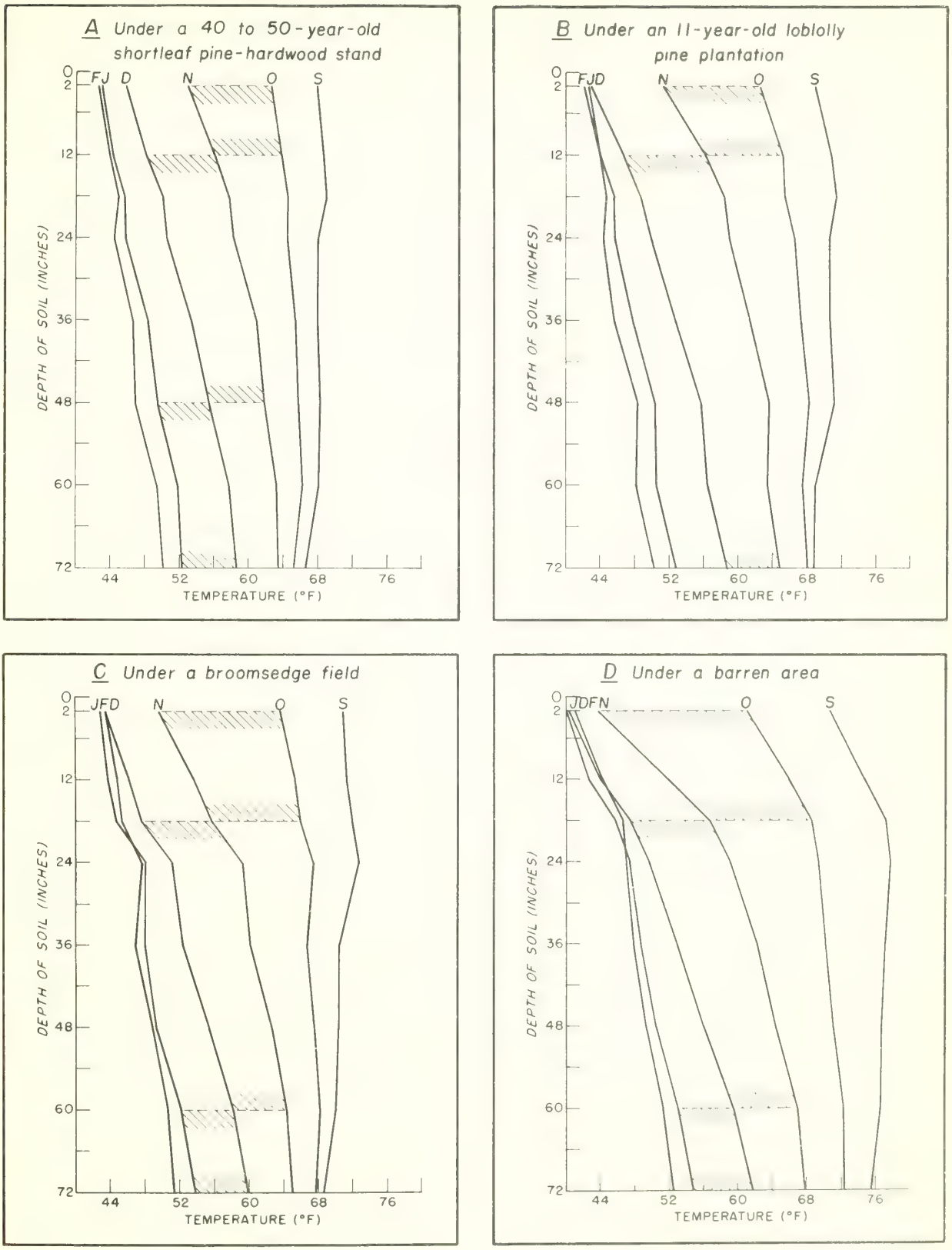

Figure 5.--Monthly average soil temperatures from September 1950 through February 1951, showing the seasonal heat loss throughout the upper 6 feet of soil. Shaded lines indicate the approximate upper and lower boundaries of depth zones undergoing the greatest heat loss for the season.

February at exposed sites, and in March at the forested areas (table 2). By the end of March, temperatures in the entire 6 feet of soil had increased from several degrees near the surface to about 1° at a depth of 6 feet (fig. 4). The period of maximum soil heating is marked by the widest divergence between successive monthly temperature profiles in figure 4. Under exposed conditions (fig. 4C and D) the upper 6 feet of soil warmed most rapidly in May as did the upper 5 feet of soil under the young pines (fig. 4B). At the barren area, for example, the upper 3 feet of soil was from 11° to 13° warmer and the 6 foot depth about 7° warmer in May than it was in April. Values for the broomsedge site were somewhat less. Under the young loblolly pines, the first 5 feet of soil was 5 to 9° warmer in May than in April, while the soil at 6 feet warmed the most in July with an increase of 4.4° over June temperatures. Under older forest cover, the upper 2 feet of soil warmed most rapidly in June, with an increase of 5 to 6° above May temperatures. An increase of about 4.5° in July marked the maximum heating from 2 to nearly 6 feet. At the 6-foot depth, the soil warmed the most in August, with an increase of 4.3° above the average temperature in July (fig. 4A).

Cooling Period

Monthly temperature profiles in figure 5 show the decrease in temperatures in the upper 6 feet of soil during the fall and winter beginning in 1950. In general, the outflow of heat from the soil began in September. By the end of October the soil had cooled to a depth of 6 feet where the decrease in temperature varied from 0.8° at the loblolly pine stand to 3.3° at the barren site. The maximum loss of soil heat in the fall and winter period extended more gradually with depth and the advance of season, in contrast to the rapid warming of the soil profiles that occurred in the spring. This lag with depth in the occurrence of maximum heat loss is indicated in figure 5 by the enclosed areas between adjacent temperature profiles, with the approximate upper and lower boundaries of given depth zones shaded to mark the largest differences in soil temperatures between successive months. In November, the maximum loss of heat reached a depth of 12 inches under forest cover and a depth of 18 inches at exposed sites. For the above zones, the decrease in soil temperatures was about 9° to 11° under forest and 10° to 17° for grass and barren areas from October to November. For the greatest portion of each soil profile, the maximum loss of heat occurred in December, with temperatures ranging from 6° to 9° lower than in November. December cooling was most rapid at the pine plantation, where the 1 to 6-foot depth cooled a maximum amount by the end of the month. Under the older forest stand, the maximum cooling of the soil in December was limited to the 1 to 4-foot zone, while the remaining 2 feet cooled most rapidly in January (fig. 5A and B). At the exposed sites, the soil from 1-1/2 to 5 feet cooled the most in December and the 6-foot depth in January (fig. 5C and D).

There were two periods, one in the spring and one in the fall, when there was very little variation of soil temperature with depth. This condition indicates that inflowing radiant heat to the upper soil layers was tending to reach equilibrium with outflowing energy from the

subsoil. For the warming period, the upper 6 feet of soil approached a constant temperature in March and April. Under the pine-hardwood stand, the least variation with depth occurred in March and was 1.9° (fig. 4A), while for barren conditions it occurred in April and was 3.5° (fig. 4D). For the cooling period, soil temperature variations with depth were least in September, with a range up to 3° for forested areas (fig. 5A and B) and 6° to 7° for exposed sites (fig. 5C and D).

DISCUSSION AND APPLICATIONS

The major differences in soil temperature among the four sites reported here are attributed essentially to the kind and amount of plant cover. The temperature of the soil depends primarily upon its ability to absorb or lose heat. Heat gains are produced directly or indirectly by radiant energy from the sun. Plant cover reduces the range of soil temperatures. Maximum temperatures are decreased by shade, and minimum temperatures are generally increased because vegetation allows less long-wave radiation from soil to sky than would occur from barren areas. Greater nocturnal radiation from the barren soil compared to the broom-sedge field was probably one reason for the lower monthly average soil temperatures at the 2-inch depth for that site (table 2C and D).

Although vegetation exerts its primary effect on soil temperatures by influencing radiation, there are indirect effects which are due to the type of plant cover. Among these is the moisture content of the soil. According to Crawford (4), a change in the amount of water present in the soil will alter all its thermal properties. Dry soil has low heat conductivity because of poor contact between the particles, with the result that temperature decreases rapidly with depth. Moisture improves the contact between particles, and conductivity increases. The specific heat, however, also increases so that the actual rise in temperature is small. For the cover conditions reported, the resistances of the fiberglas elements in August indicated that soil moisture had been depleted to the wilting point under forest vegetation but was well above that limit under grass and barren sites, at least in the 3 to 6 and 4 to 6-foot depth zones. It is quite likely that the higher moisture content of the exposed sites materially aided the inflow of heat in the summer and was largely responsible for the greater depths to which the annual maximums penetrated in August compared to the forested areas (table 2). Although the subsoil was relatively wet at the barren and broomsedge areas in August, the upper 2 or 3 feet was dry. The lower heat conductivity of this drier soil in the upper layers may have accounted for the delay in the occurrence of maximum heat loss at the exposed sites in the winter period (fig. 5). Differences in the thermal properties of sand and clay would account for some of the temperature variations among the sites at the 2-inch depth, particularly between the barren and grass areas. Sand for example, has a lower specific heat by volume than clay, and when dry, will heat more rapidly. Organic matter has a lower specific heat than either sand or clay (4). Consequently, the upper levels of the sandy topsoil layer at the broomsedge field would tend to heat more rapidly in summer and cool

faster in winter, as compared to the layer of clay near the surface at the barren area. At the forested sites the effect of organic matter in the forest floor would be obscured by the influence of the canopy overhead.

Much of the usefulness of soil temperature information lies in evaluating its effects upon root growth. Such evaluation, however, is inherently complex since the process of growth itself is complicated and the study of roots in place has many limitations. It is known, however, that plant roots elongate rapidly at favorable soil temperatures. Barney (1) found that the primary roots of 2-1/2-week-old loblolly pine seedlings grew most rapidly between 68° and 77°. Growth continued at 41° and 95° but was less than 10 percent of the maximum rate. Contrary to common opinion, it is possible that the roots of many forest trees are not necessarily dormant during the winter months but may continue to grow when the soil temperature rises above a minimum of approximately 41°. Assuming that the upper and lower temperature limits for root growth found by Barney (1) are applicable to the pine stands reported in this study, temperatures in the upper 6 feet of soil would seldom limit root growth. February for example, was the coldest month, but soil temperatures averaged 1° or more above the lower limit at the 2-inch depth. At greater depths the temperatures of the soils were increasingly favorable for root development. At a depth of 5 and 6 feet the minimum temperature at all sites ranged from 48° to 52°, which is well above the 41° minimum for root growth. On the other hand, the optimum temperatures for root elongation occurred from June to October. It is pointed out, however, that root growth in summer may frequently be curtailed by inadequate supplies of soil moisture.

Although this study was not designed to determine soil temperature effects upon root growth, the temperature information provided may be helpful in soil management on Piedmont lands. For one thing, only near the surface is the temperature of barren heavy clay soils too high for satisfactory root growth. In the upper 2 feet of the barren soil, temperatures in July and August ranged up to several degrees above the optimum for root growth. Temperatures at the surface of such land may reach extreme proportions. At a site comparable to the one reported here, maximum summer temperatures have been measured as high as 136° at a depth of 1/4 inch. For a 15-day period in July (1950) the average daily maximum at 1/4 inch was 119° (2).

But mulch of hay or pine boughs is sufficient to reduce these surface soil temperatures to a level that permits root growth. Apparently a density of living cover similar to average old field broomsedge is sufficient to prevent damaging surface-soil temperatures. Such a cover can be obtained from cool-season plants such as winter ryegrass, oats, vetch or crimson clover. These plants can be established on most barren areas by fall sowings which are limed and heavily fertilized. By making their growth during cool weather, these cover crops escape high soil temperatures and if they are allowed to stand, their dead foliage shades the soil, permitting establishment of summer growing species. Whether it is cheaper to use a mulch of dead plant material or establish a cover crop depends upon accessibility, labor costs, etc., but either system will reduce the damaging high temperatures to a safe level. Some such measure is recommended before barren sites are planted to trees.

Temperature data from this study may also aid investigations of tree root growth. The fact that subsoil temperatures do not limit root extension during winter may explain the penetration of pine roots into compact soil layers. During the winter such soil layers are moistened and may allow roots to grow into and through them, but in summer the same soils are drier and often too dense to allow penetration.

Soil temperatures also influence moisture gradients in the soil. It is intended to explore this subject in an analyses of soil moisture records.

SUMMARY

Temperatures are reported for the upper 6 feet of soil under four site conditions in the South Carolina Piedmont from September 1950 through October 1951. The data were obtained as part of the procedure of determining soil moisture by the electrical resistance method at a barren site, a broomsedge field, an 11-year-old loblolly pine plantation, and a 40 to 50-year-old shortleaf pine-hardwood stand. Daily observations of temperature at selected depths in the profiles were averaged by months and presented in tabular and graphical form.

Presence of vegetation had the greatest effect on soil temperatures in summer, with profiles tending to be progressively cooler from barren to high forest conditions. Soil temperatures were generally lowest in February and highest in August. Soil heating to a depth of 6 feet began in March and ended in September or October. Under barren conditions the soil at a depth of 18 inches averaged about 47° in February and 82° in August, while under the pine-hardwood stand the temperatures were 45° and 71° respectively. At a depth of 6 feet, soil temperatures in February were from 50 to 52° regardless of cover conditions. In August, the temperatures at 6 feet ranged from about 66° under forest cover to 74° for barren conditions. Annual extremes of soil temperature occurred up to 2 months later than mean air temperature extremes. There was also a lag of from 1 to 2 months in the occurrence of the annual extremes with depth.

The significance of the data is discussed in the light of known effects of temperature on root growth. For conditions reported, the roots of loblolly and shortleaf pine may grow throughout the year. The high soil temperatures that preclude root growth on barren areas are apparently confined to a thin zone near the surface. Living cover similar to an average broomsedge field is believed sufficient to markedly reduce these surface soil temperatures. It is suggested that winter cover crops be planted on barren areas as a means of reducing high soil temperatures before such sites are planted to trees.

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Logging Methods and Costs in the Southern Appalachians

by

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LOGGING METHODS AND COSTS IN THE SOUTHERN APPALACHIANS

by

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INTRODUCTION

Most timber operators have a fair idea of their total logging costs but have not taken the time to examine the separate cost components. Consequently, they do not know where to start reducing costs when the profit margin shrinks below the acceptable limit. Logging factors such as tree size, species, accessibility, type of equipment, and method of operation are all-important in determining final costs; hence the effect of each should be known to the appraiser and operator. Furthermore, logging cost information by tree size is needed before the financial maturity of a tree or a stand can be determined.

Formal study of logging costs in the Southern Appalachian region is not new. Most of the early studies, however, are no longer useful because of radical changes in equipment and methods. In some cases results were expressed in terms of dollars and cents, and were of value for a few years only--until wage rates and other costs changed. In 1946 Shames (8) presented the results from a single but not necessarily average operation in this region. The present study is more complete in showing how production costs vary between species or species groups, and in comparing the cost of alternate methods, so that an operator can choose the best method and the most suitable equipment for his own conditions.

The results reported here are based on studies of some thirty different logging operations conducted within a 75-mile radius of Asheville, N. C., from 1947 to 1952.

NATURE OF STUDY

The object of the study was to determine the relationship of species, tree size, type of equipment, alternate methods, and other factors to the time required for felling, bucking, skidding, loading, and hauling of Appalachian species--largely hardwoods. The study includes a comparison of hand and power log making, team and tractor skidding, hand and power loading and

truck hauling over different classes of roads. Stand volume cut or left was not included as a study item.

As indicated above, these studies were made on many different logging chances representing all types of operators and job sizes. Most of the studies included samples taken at different seasons so that seasonal effects were averaged. When the first hand-felling studies were started in 1947, power saws were just coming into use (3); consequently, they were not studied then. However, they were carefully studied in 1951 and 1952. Team and tractor skidding were likewise studied at different times, except that both were studied on the same job when possible.

The location of the studies ranged from flat land to steep mountainsides. Differences in topography usually result in differences in species occurrence also. Consequently, our studies included all of the common species and a few of the uncommon ones. Stands of mixed hardwoods predominated, however, so that special efforts were required to obtain data on such species as white pine. The types of equipment used and the operating methods studied were the ones most commonly used. Such operating methods as cable logging were too rare and expensive to justify much study time.

A check study of seven of the larger logging operations within the study area was made just before publishing this report to compare computed costs with current contract or force-account costs, and adjustments were made when it was considered advisable.

For practical purposes we have used trees of average height for a given diameter in tabulating felling and bucking time per M board feet by species groups. The smaller trees averaged only one log, while trees 24 inches d.b.h. and over contain three logs. A change in the number of logs per tree compared with the average used will affect time and costs. More logs will reduce the time per M board feet, and fewer logs will increase it.

The average tree volumes used in this report are derived from those computed for the North Carolina Survey Unit No. 4 (mountain area), by T. C. Evans of the Southeastern Forest Experiment Station. Different average tree volumes will also change the time and cost requirements per M board feet, for felling and bucking especially, and also skidding and loading to a lesser extent. For example, an increase of 30 board feet in the average tree volume at 14 inches d.b.h. will reduce the time requirements per M board feet some 25 percent.

Delay times were the usual ones encountered on the job and do not include such lost time items as storms or other unusual delays exceeding an hour. Some of these will be discussed below under the various operations.

Throughout the study the International 1/4-inch log rule is the basic unit of measurement. All time and cost data, unless otherwise indicated, are per thousand board feet (hereafter referred to as M b.f.). To convert these data to Scribner scale, approximately 10 percent more time will have to be added to all diameters. See table 77 in Reynolds' publication (6) for a comparison of time and cost for the various log rules.

LOG MAKING

The term log making includes felling, limbing, and bucking. This phase of the study covers both hand and power equipment. The hand equipment is the type used in the mountains for the past 50 years or more. It consists of a two-man crosscut saw 5 to 6 feet long, an ax (usually double bitted), a pair of iron wedges and an iron or wooden maul for driving the wedges. The power equipment included both one- and two-man gasoline-motor-driven chain saws, but even the one-man saw was operated by two men in the felling stage. Three makes of power saws were included, but comparison of the relative efficiency of the different saws was beyong the scope of this study. Crew size for each method ranged from two to four men. Tree diameters ranged from 8 to 50 inches, and tree length ranged from one to five logs per tree.

The number of trees cut by each method was approximately the same (164 by hand, 188 by power), and species distribution was also similar. The hand-tool data were collected on 13 operations, while the power tools included only six operations.

Separate time was kept for each phase of the operation by tree and log size. While the pocket watch was accurate enough for hand tools, a stop watch was used with power saws. Regression analyses were made for each phase of log making and then combined to produce the times shown in table 1 for each tree d.b.h. class. In the final regression equations given below, T is log-making time in man-minutes per tree, and D is d.b.h. of the tree.

Hand methods, hard hardwoods:

$$T = .17D^2 + 29.75 \qquad (I)$$

Hand methods, pine and soft hardwoods:

$$T = .145D^2 + 24.1 \qquad (II)$$

Power methods, all species:

$$T = .055D^2 + 4.6 \qquad (III)$$

The final terms of the above equations include average delay time, which amounted to 22.9 man-minutes per tree for hand methods (Equations I and II), and 3.0 man-minutes for power methods (Equation III).

The man-hour requirements shown in table 1 and figure 1 are for average workers in average timber, with no lost time for travel or bad weather. Shames (8) found such lost time amounted to 8 percent of the day's total time. Costs in table 1 are based on hourly rates which are derived in tables 7 and 8 of the appendix.

The major factor affecting log-making time was the type of equipment used. Man-hour requirements for log making with power saws averaged only about one-third those for hand tools (fig. 1), while dollar costs per M b.f. were only about half of those for hand tools (table 1).

Table 1.--Relation of tree size to time and cost of felling, trimming, and bucking trees of difference species groups with hand and with power tools

HAND

D.b.h. (Inches)	Hard hardwoods				Pine and soft hardwoods			
	Time per tree [1]	Vol. per tree	Time per M b.f.	Cost per M b.f.	Time per tree [1]	Vol. per tree	Time per M b.f.	Cost per M b.f.
	Man-hours	B.f.	Man-hours [2]	Dollars [3]	Man-hours	B.f.	Man-hours [2]	Dollars [3]
10	--	--	--	--	.65	40	15.0	14.25
12	--	--	--	--	.75	80	9.2	8.75
14	1.05	70	14.0	13.30	.88	140	6.6	6.25
16	1.22	110	10.8	10.25	1.02	200	5.2	4.95
18	1.41	160	8.8	8.35	1.18	280	4.4	4.20
20	1.63	220	7.6	7.20	1.36	370	3.8	3.60
24	2.13	350	6.2	5.90	1.79	560	3.1	2.95
30	3.04	590	5.2	4.95	2.58	910	2.7	2.55
36	4.17	800	4.8	4.55	--	--	2.6	2.45

POWER

10	--	--	--	--	.162	40	3.50	5.25
12	--	--	--	--	.210	80	2.20	3.30
14	.258	70	3.25	4.90	.258	140	1.80	2.70
16	.316	110	2.75	4.10	.316	200	1.60	2.40
18	.375	160	2.40	3.60	.375	280	1.40	2.10
20	.445	220	2.15	3.20	.445	370	1.30	1.95
24	.590	350	1.75	2.60	.590	560	1.10	1.65
30	.903	590	1.55	2.30	.903	910	1.00	1.50
36	1.270	860	1.45	2.20	1.270	--	.95	1.40

1/ The time data are based on two-man crews already on the job.

2/ Man-hours are curved values rounded to nearest .10 m.h. for hand and nearest .05 m.h. for power tools.

3/ Dollar costs are based on hourly rates of $0.95 and $1.50 for hand and power tools respectively, and are rounded to nearest 5 cents (see appendix tables 7 and 8 for derivation).

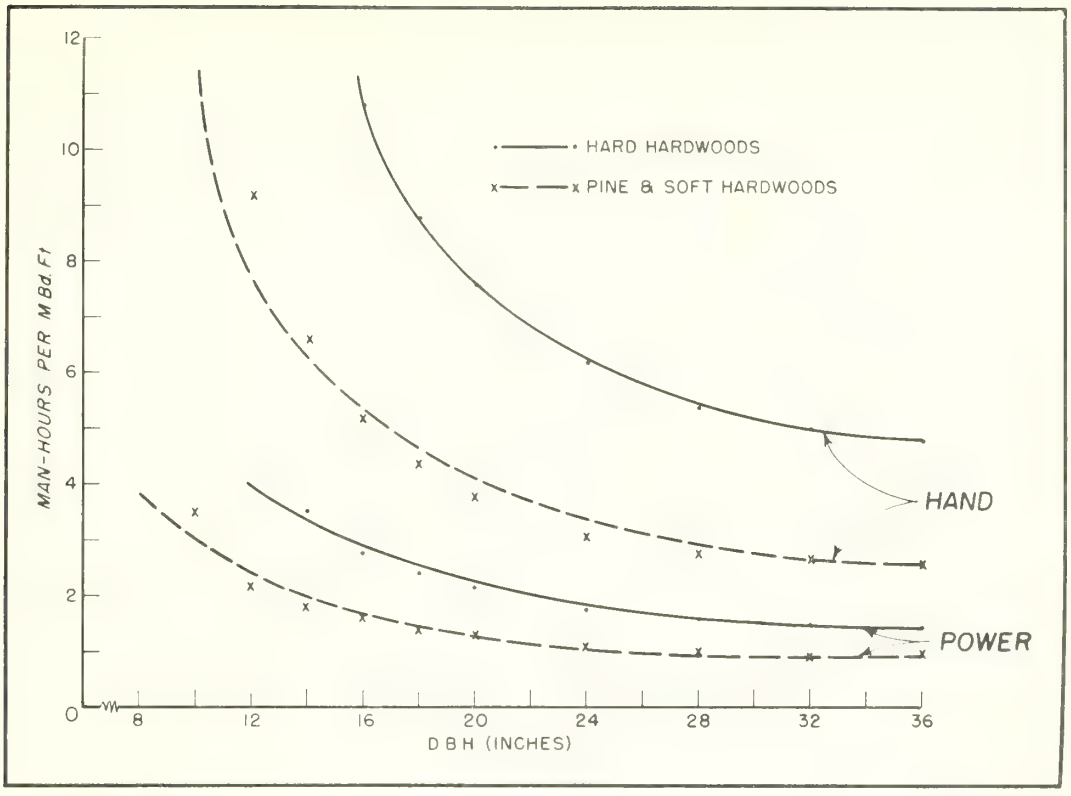


Figure 1.--Relation of felling, trimming, and bucking time to tree size for different species groups and for hand and power tools.

For a given type of equipment, tree size had the most important bearing on log-making time. For example, the time for all species for hand methods decreased with tree size from 9 hours per M b.f. for 14-inch trees to less than 4 hours for 36-inch trees. With power saws, tree size had somewhat less effect on log-making time (2-3/4 man-hours for 14-inch trees and 1-1/2 man-hours for 36-inch trees).

The above relationships are for trees of average merchantable height for their diameter class. Within a given diameter class, the tree volume and number of logs have an additional effect on log-making time. The taller the tree and the greater its volume, the less is the time required per M b.f. for log making.

The third factor influencing log-making time was species of tree. The major variation was accounted for by grouping the species into (1) hard hardwoods, and (2) pine and soft hardwoods. Time requirements per M b.f. for a given diameter class were about twice as high for hard hardwoods as for yellow pine and soft hardwoods when cut with hand tools. Limited data indicate that time requirements for white pine are similar to those for soft hardwoods.

Further examination of the data showed that the difference between species groups was less with power saws than with hand tools (fig. 1). Since felling time alone was about the same for all species, group differences became important only in trimming and bucking operations.

The difference between species groups is much greater when the results are expressed in terms of man-hours per M b.f. than as man-hours per tree. The reason is that for a given diameter class, the pine and soft hardwood group has a considerably higher average volume per tree over which to prorate the log-making time, as shown in table 1.

Size of crew was an important factor in the time requirements for log making with hand tools. Our observations show that the addition of a third man to a crew is rarely profitable. Lost time averages more per tree with three or more men than with two. Consequently three- and four-man crews increase the basic man-hour requirements for hand tools from one-third to one-half.

Contrary to the findings with hand tools, the size of the power-saw crew had little effect on man-hour requirements per M b.f. within the range of crew size studied (two to four men). However, Weitzman (11) found a one-man crew to be more efficient than a two-man crew on a power-saw operation in West Virginia.

Delay time is more important for power than for hand tools, since the fixed cost for equipment represents a much larger proportion of total hourly costs in the case of power equipment. Delay times were found to average much less in the case of power saws.

Incentive appeared to play a large part in the output of power-saw crews. Those crews working by the hour took no longer to cut down or buck a tree than those working at a contract rate, but the number and length of delays between trees was much higher for the hourly paid employees.

While the time and cost data shown apply to average conditions, they must be increased for the more difficult logging chances. Thus, on steep mountain jobs where travel was difficult and trees were scattered and short, costs were found to be double or even triple those shown in table 1.

SKIDDING

When this study was started, ground skidding was the only accepted method for moving logs from the stump to the mill or roadside over much of the Southern Appalachian area. Since then a few cable logging jobs have been completed but they are quite rare and usually require a large capital outlay. Another and newer method, still rare in this area, is the use of the arch or rubber-tired sulky pulled by a tractor. This device and method is being used on the Fernow Experimental Forest.1/

The study reported here sampled the most common types of motive power now in use in the Appalachians--teams, light tractors (D2 and TD6), and medium tractors (D4 and TD9). The range of conditions sampled for each type of equipment is tabulated as follows.

1/ A part of the Mountain State Research Center (Northeastern Forest Experiment Station), with headquarters at Elkins, West Virginia.

	Team	Light tractors	Medium tractors
Trips . . . . . number	335	72	60
Load size			
Minimum . . . . board feet	20	200	150
Maximum . . . . board feet	800	900	1650
Average . . . . board feet	200	475	650
Distance			
Minimum . . . . . chains	1	4	5
Maximum . . . . . chains	16	20	50
Average slope . . . percent	0-100	0-40	0-50

The job of skidding was timed in five parts: (a) hooking, (b) travel to the landing, (c) unhooking, (d) return time, (e) delays. Additional data for each turn included diameter, length and species of log, length of the trip, and degree of slope.

Separate regression analyses were made for travel time and hooking time for each type of equipment with various distances, load sizes, slopes, and species combinations. Below are the regression equations used for computing skidding time in crew minutes per trip (T) for different skidding methods:

Team:

$$T = 4.52 + .67D + 1.48\ (VmDS) + .60\ (VmDC) + 1.61L$$

D2 and TD6 tractors:

$$T + 6.54 + .53D + 1.08\ (VmDS) + .338\ (VmDC) + 4.40L$$

D4 and TD9 tractors:

$$T = .36 + .94D + 1.6L$$

D is the distance in chains--one way
L is the number of logs
S is sine of the slope in degrees
C is cosine of slope in degrees
Vm is load volume in M b.f.
Delay time is included in the initial constant of each equation

Only the variables which had a significant effect are included in a given equation. Note that the more the horsepower the fewer the important variables; with ample power the degree of slope and load volume become less important.

Skidding time (converted from minutes per trip to crew-hours per M b.f.) for the three types of equipment are compared in figure 2. Although loads of different board-foot volume are shown, the diagram is restricted to loads of two or four logs in order to simplify the comparisons.

Skidding time was least for the D4 and TD9 tractors. Teams were somewhat faster than D2 and TD6 tractors except for larger loads skidded over long distances (fig. 2).

But skidding time per M b.f. is not the whole story, nor is it the answer desired by the operator or the timber appraiser. Consequently, crew-hours were converted to dollars per M b.f. and are illustrated in figure 3. In this figure average load sizes are assumed to be 200, 400, and 800 board feet, while full loads are assumed to be double the average or 400, 800, and 1600 board-feet for team. small tractor and medium tractor respectively. Medium tractors were consistently the cheapest motive power for all distances and load sizes, and teams were second. The D2-class tractor doesn't seem to be a very practical machine for the Southern Appalachians. In skidding costs it ranks a poor third because of high operating cost in relation to its speed and load size. Subsequent comparisons with respect to load size, distance, slope, and other factors, therefore, will be made only between the team and the larger tractors (D4, TD9).

Size of load was the most important single variable studied for each type of equipment, ranking ahead of distance as a cost factor. A study of the data in figure 3 or table 2 will show that when load size is held constand, doubling the distance increases cost per M b.f. from one-fourth to three-fourths--averaging one-half. When distance is held constant, halving the load size more than doubles the cost per M b.f. This matter of loading to capacity can hardly be overemphasized whether for team or tractor.

Following is a brief summary of load sizes by type of equipment as found in this study. Team loads averaged 90 b.f. for 227 trips, all of which were skidded less than 9 chains and up to 20-percent slope. For longer trips and steeper slopes the loads averaged 280 b.f. for 27 loads. For 78 different trips, timed by Shames (8), the team loads averaged 225 b.f. and all but four of these were skidded less than 7 chains.

In the case of the D4, full loads up to 1600 b.f. were sometimes skidded, but the average load for all 60 trips was only 650 b.f. Steep slopes usually prevent maneuvering for full loads. There was also a tendency to underload on the short hauls. This tendency was especially noticeable on one job where for 23 trips averaging 12 chains or less and 12-percent slope or less, an average of only 300 b.f. per trip was hauled, but for longer trips and steeper slopes on this same job the loads averaged 740 b.f.

Although load size in terms of board feet is a convenient figure to work with, tree d.b.h. and its relation to skidding time and cost is much more useful to the timber appraiser and the more skilful timber contractors. This is true because tree size is basic to most uses of logging costs; hence skidding costs are desired for the same unit. Tree size has an important bearing on skidding costs because the small logs from small trees limit the board-foot load that can be skidded on one trip. In constructing table 2

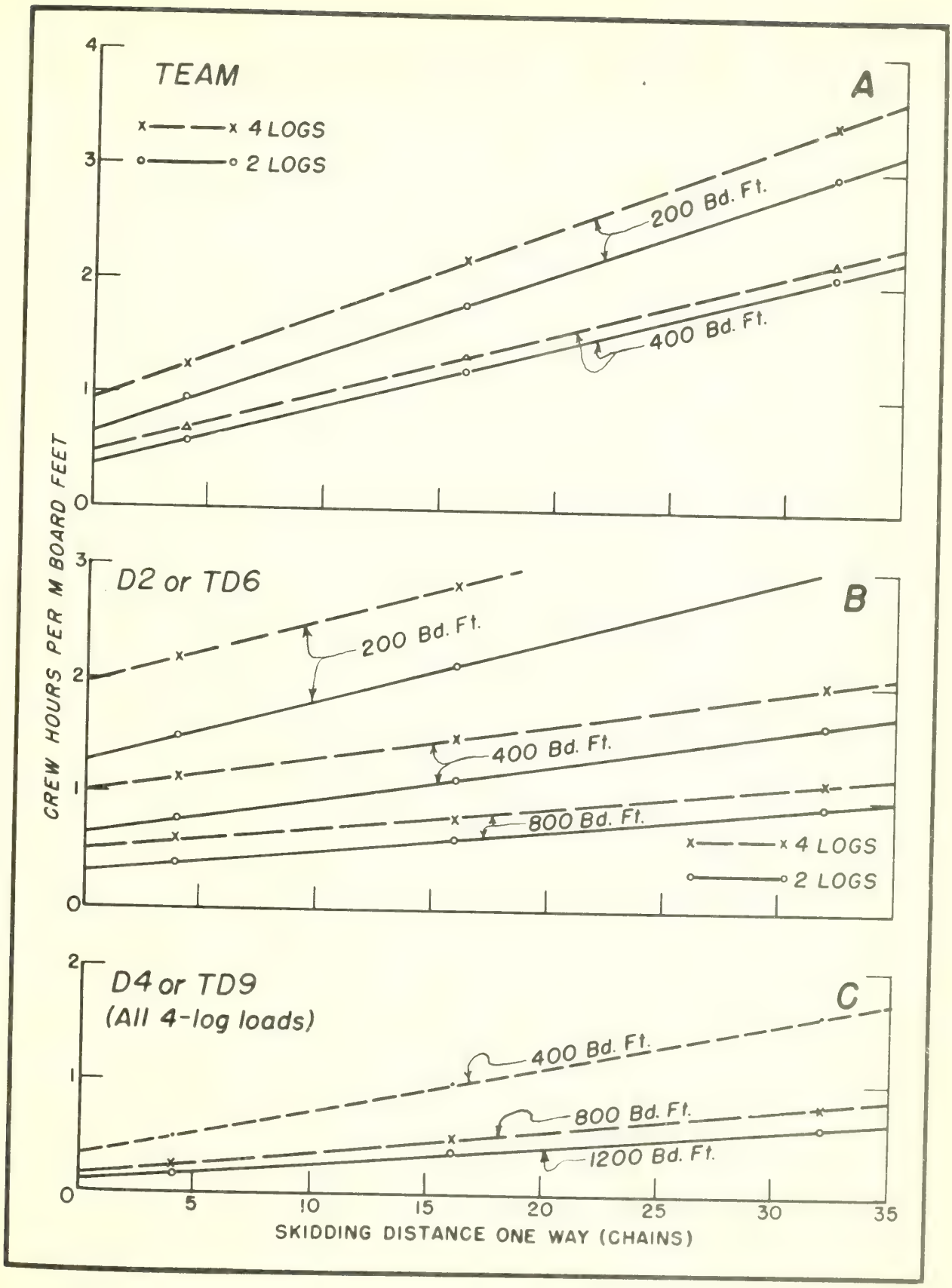


Figure 2.--Skidding time per M b.f. on 20-percent slope for various load sizes, distances, and for two types of equipment.

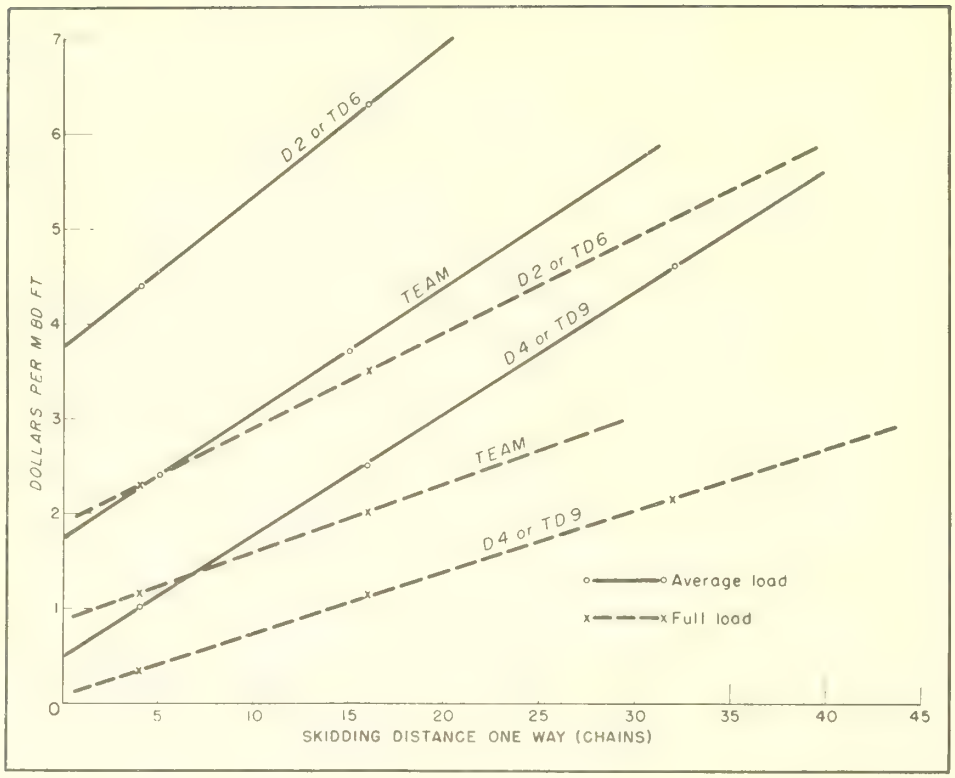


Figure 3.--Skidding costs per M b.f. on 20-percent slope for team, D2-, and D4-class tractors with average and full loads.

and figures 3 and 4, full loads of small trees were considered to be six logs for the team and eight for the tractor. Hooking time was prorated for the appropriate number of logs per trip. Tractor load volumes were limited to double those for the team, which is conservative though in line with the usual practice observed. Minimum team (no swamper) and maximum tractor rates were used--the latter, because mountain logging usually wears out such equipment faster than average use.

Difference in size of load is the major reason for the difference in cost of skidding between our study and a recent TVA study (9). We used full loads for all tree sizes in computing team and tractor costs, whereas they used smaller loads. This difference resulted in skidding costs double or triple ours.

A study of figure 4 will show that team skidding is cheaper only for small trees and short distances, and then only when no swamper time is included. The addition of a swamper for only half time makes tractor logging cheaper at all distances for trees larger than 16 inches. Even with no swamper time for the teams, the larger trees (20 inches and over) can be moved cheaper by tractor (D4 and TD9). The fact that tractor loads are assumed to be only double those for team, whereas they could well be three times the team load, makes the tractor showing rather conservative in these comparisons. Furthermore, the tractor's economy is not realized with small loads. Extremely rough ground or scattered timber will also result in higher costs--up to double those shown in table 2.

Table 2.--Skidding costs per M b.f. by tree size on 20-percent slope

Distance and d.b.h.	Team				Medium tractor		
	Load size	Crew time		Cost at 1/ $1.85, all species	Load size	Crew time	Cost 1/ at $5.10
		Hardwood	Pine				
	B.f.	Hours	Hours	Dollars	B.f.	Hours	Dollars
4 chains							
12 inches	200	1.30	1.20	2.30	400	.60	3.05
16 "	250	.95	.85	1.65	500	.35	1.80
20 "	300	.80	.70	1.40	600	.22	1.10
25 "	300	.70	.55	1.15	600	.20	1.00
30 "	400	.55	.45	.90	800	.15	.75
36 "	600	.45	.30	.75	1200	.08	.40
8 chains							
12 inches	200	1.60	1.50	2.85	400	.75	3.80
16 "	250	1.20	1.10	2.15	500	.45	2.30
20 "	300	1.05	.90	1.80	600	.35	1.80
25 "	300	.95	.75	1.55	600	.30	1.55
30 "	400	.80	.60	1.30	800	.20	1.00
36 "	600	.70	.45	1.00	1200	.15	.70
16 chains							
12 inches	200	2.15	2.05	3.90	400	1.05	5.35
16 "	250	1.80	1.60	3.15	500	.70	3.55
20 "	300	1.60	1.35	2.70	600	.55	2.80
25 "	300	1.50	1.10	2.40	600	.50	2.55
30 "	400	1.35	.85	2.05	800	.35	1.80
36 "	600	1.20	.70	1.75	1200	.25	1.25
32 chains							
12 inches	--	--	--	--	400	1.40	7.15
16 "	--	--	--	--	500	1.15	5.85
20 "	--	--	--	--	600	1.00	5.10
25 "	--	--	--	--	600	.90	4.60
30 "	--	--	--	--	800	.65	3.30
36 "	--	--	--	--	1200	.45	2.40

1/ Values rounded to nearest 5 cents. For derivation of hourly costs, see tables 8 and 11 in the appendix. Team cost does not include swamper. Tractor rates used are the maximum.

Actual travel time per M b.f. was not appreciably affected by the number of logs pulled for either team or tractor. It was only in the hooking phase of skidding that the number of logs became important. Each additional log added about 1.6 minutes of hooking time for both team and large tractors. The number of logs for teams especially and for tractors practically, is limited by the number of sets of grabs or dogs which can be dragged. Three sets of grabs (or enough to make a train of four logs) was the usual maximum for a team, and five sets was the usual limit studied for a tractor. Although a few tractors were observed carrying more than five sets, the resultant load of logs, hitched abreast rather than tandem, knocked down an undue amount of reproduction and exposed more soil to erosion than necessary.

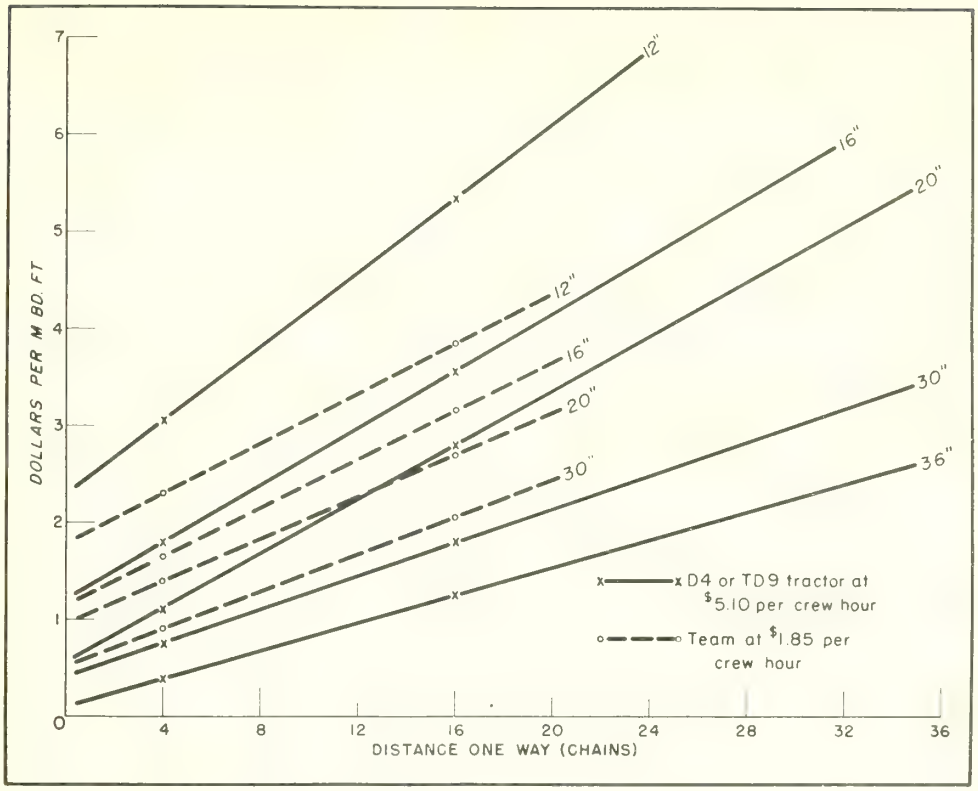
Steepness of slope increased the skidding time per M b.f. for teams because of the added rest time required by the team when returning uphill. The added uphill travel time of the team is not offset by increased downhill speed. There is, however, an offsetting influence of steep slopes not covered in the studies reported earlier, and that is on load size. Larger loads can be skidded down steeper slopes, although this principle is often overlooked in practice. While 300 board feet may be a capacity load for a team on level terrain, 1000 board feet may not be a full load when the slope is 100 percent.

Tractor skidding time per M b.f. did not increase significantly with increased steepness of slope up to 40 percent. However, manufacturers do not recommend trying to operate tractors on adverse slopes exceeding 50 percent, because of unsafe operating conditions and rapid loss of tractor efficiency.

Species composition had little effect on skidding time except for team skidding. Here skidding time was apparently slightly less for small loads of hard hardwoods than for pine or soft hardwoods, while for average loads there was little difference. For large loads (400 or more b.f.), team skidding time was about one-third less for pine or soft hardwoods than for the same size load of hard hardwoods. Species composition did not significantly affect skidding time with tractors.

Delay time in skidding is a relatively small item in contrast to its importance in felling and bucking. Total delay time for teams averaged 2.8 minutes per trip compared with a delay time average of 2.1 minutes per trip for all sizes of tractors. The delay times include only those connected with the working time and do not include delays due to bad weather or travel to and from the job. Shames (8) found the latter type of delays amounted to 30 percent of the total possible work time. Although our observations indicate this amount is probably too high, an increase of 20 percent in the cost data shown in table 2 and figures 3 and 4 would be justified.

A regular ground skidder is usually much cheaper to operate on uphill skidding than is a tractor because of lower hourly cost and a faster take-up drum. Power skidding uphill for distances up to 6 chains (400 ft.) can be done at a cost roughly comparable to that shown for tractors (D4 or TD9) skidding downhill the same distance. Beyond 400 feet, power skidding time and cost go up very rapidly.



4.--Skidding costs per M b.f. for team and D-4 class tractor, by tree size, 20-percent slope.

Data furnished by the Caterpillar Co. indicate that a tractor equipped with a sulky and logging tree length loads can double hourly or daily production at a cost increase of only 10 percent. Observation and tentative data from the Fernow Experimental Forest indicate that soil damage for this method is less than for any of the direct skidding methods studied.

TRUCK LOADING

Truck loading by hand and by power were both studied. Truck sizes ranged from 1-1/2 tons to 2-1/2 tons. Hand loading was all from natural banks or prebuilt log cribs. No team or cross-haul loading was found. The power loading was all done by means of a "skidder-loader." Such a machine is commonly constructed of scrap material by a local shop man and roughly resembles the "Loggers Dream."2/ It usually consists of a fairly new Ford or Chevrolet motor mounted in back of the cab of an old truck. A pole A frame is mounted on the extreme rear end of a truck. The extra motor powers a single drum located between the A frame and the extra motor (fig. 5).

2/ A patented machine manufactured by the Taylor Machine Works of Louisville, Miss.

Loading is done with the aid of power equipment on all but the smallest operations. Although the hand-loading part of our study was rather limited, it failed to show any radical disadvantage compared with power loading. Probably the greatest advantage of power is in flat country, where bank loading points are nonexistent or so far away that skidding to them is uneconomical. In the mountains, bank-loading spots can usually be found without much difficulty, and power loading is more efficient only in coves, in other level topography, or when logs are both skidded and loaded by the same machine.

Power loading data were collected for 29 loads containing a total of 415 logs which scaled 47 M b.f., while hand loads totaled 9.5 M b.f. in 13 loads.

Figure 5.--Power loader in operation.

Loading time per load for power equipment was found to be closely related to the number of logs per load and the volume of the load in M b.f. (fig. 6). In addition there are the relatively fixed time elements of binding, unloading, and delay. These total 10 minutes per load regardless of number of logs or size of load.

The extent to which small logs increase the loading time per M b.f. is shown in the following tabulation from figure 5, using a constant load volume of 1500 b.f.:

Load	Man-hours	Man-hours per M b.f.
5 logs	1.2	0.8
10 logs	1.5	1.0
20 logs	2.1	1.4

Time and cost data for other load sizes and number of logs can be obtained by computation. Separate computations for trees of the two species groups were made, but the time and dollar differences were so small that only the average for all species is shown in table 3.

TRUCK HAULING

Hauling is the first item of logging cost to be discussed which is independent of tree or log size, assuming full loads are being hauled. Load size is usually limited by a combination of legal load restrictions and the quality of woods roads. It can be readily seen that once the logs are loaded other factors than log size, such as type of road and distance, are the primary factors controlling hauling costs. Furthermore, this phase is the only one on which we have done but little original work. We have, however, checked travel time by road types. Operating costs are based on Reynolds' (7) recent studies.

Truck operating expenses have been added to hourly fixed costs prorated according to travel time and the total cost computed for various distances. These costs and the corresponding travel times are shown in table 4. Since these costs are not appreciably affected by load volumes ranging from 1 to 2 M b.f., the user should remember to divide total costs by M b.f. hauled to get costs per thousand board feet.

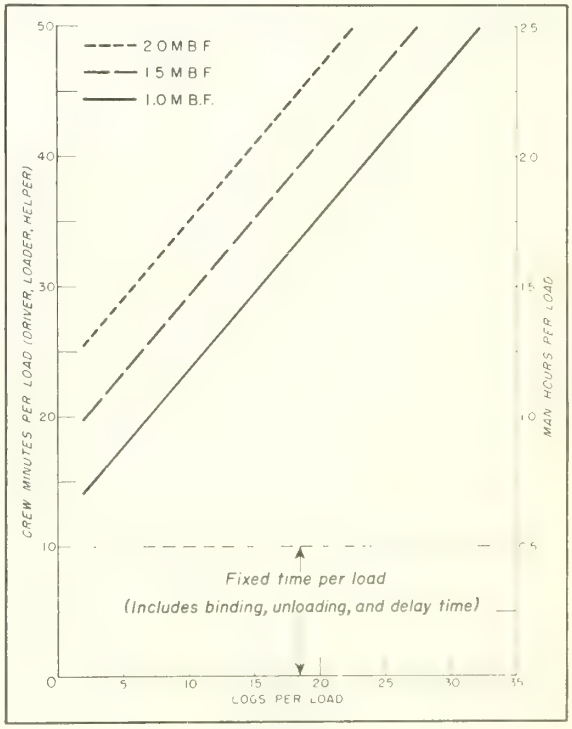


Figure 6.--Power loading time per M b.f. for trucks carrying loads of 1, 1-1/2, and 2 M b.f., as affected by the number of logs per load.

Table 3.--Truck loading time and cost with power loader in relation to tree size, with loads of one M b.f.

D.b.h. (Inches)	Logs per M b.f.	Time[1] per load	Loading cost[2]	Truck stand-by cost[3]	Total cost per load[4]
	Number	Crew-hours	Dollars	Dollars	Dollars
12	25	.69	1.90	1.14	3.05
16	13	.45	1.24	.74	2.05
20	9	.37	1.02	.61	1.60
24	6	.31	.85	.51	1.35
30	4	.27	.74	.45	1.15
36	2-1/2	.24	.66	.40	1.05

1/ Loading time per load derived from regression formula: Time in crew-minutes per load, including loading and unloading = 11.44 M b.f. + 1.2 number logs.

2/ Loading cost is based on a machine rate of $2.75 per crew-hour (See table 10).

3/ Loading time in crew-hours multiplied by $1.65 per hour (includes driver) for truck stand-by time. (See table 11 for derivation of truck rate.)

4/ Values curved and rounded to nearest 5 cents.

Table 4.--Truck hauling time and cost[1] per trip

Trip dist. 1 way (Miles)	Woods road				Hard surface road			
	Total[2] travel time	Run[3] expense at $0.50	Fixed[4] cost at $1.65	Total[5] cost	Total[2] travel time	Run[3] expense at $0.24	Fixed[4] cost at $1.65	Total[5] cost
	Hours	- - - Dollars - - -			Hours	- - - Dollars - - -		
1	.33	.50	.54	1.05	.10	.24	.16	.40
2	.67	1.00	1.10	2.10	.20	.48	.33	.80
3	1.00	1.50	1.65	3.15	.30	.72	.49	1.20
4	1.33	2.00	2.20	4.20	.40	.96	.66	1.60
5	1.67	2.50	2.75	5.25	.50	1.20	.80	2.00
10	3.33	5.00	5.50	10.50	1.00	2.40	1.65	3.05
15	5.00	7.50	8.25	15.75	1.50	3.60	2.50	6.10
20	6.67	10.00	11.00	21.00	2.00	4.80	3.30	8.10
30	--	--	--	--	3.00	7.20	4.95	12.15
40	--	--	--	--	4.00	9.60	6.60	16.20

1/ Time and cost data are for 1-1/2- or 2-ton trucks. Costs per trip are for loads of 1 M b.f. and should be increased for larger loads.

2/ Based on average speeds of 6 m.p.h. on woods roads and 20 m.p.h. on paved roads.

3/ Running expenses are from table 11 (appendix) and have been doubled for round-trip values.

4/ Fixed costs are from table 11.

5/ These are costs per load of 1 M b.f. and are rounded to nearest 5 cents.

It has been found that hauling time per mile and the resultant cost varies inversely with the hardness of the road surface and alignment--other conditions remaining equal. Earlier studies (2,5) show travel time for three or four types of roads. Reynolds' report (7) shows cost data for only two--(a) woods, (b) graded dirt or better. Shames data (8) indicate approximately equal round-trip speed per mile for gravel and black-top pavement. Probably two road classes (highway and woods) are adequate.

Since there are several classes of woods roads, the following brief description will explain our version of a woods road. Such a road is only roughly graded--but not surfaced. Consequently, it is not an all-weather road, but can be used most of the year if it is not traveled during or immediately following rains. Grades are generally favorable to the loaded truck. Speeds up to 10 m.p.h. are possible on the better stretches but speeds of 3 to 8 m.p.h. are more common. Reynolds (7) found that running costs per mile on graded dirt or better roads (including pavement) are approximately half of those for woods roads. Although we have travel time for lower quality roads than described above, we do not have accompanying operating costs. However, we did increase operating costs for mountain dirt roads by approximately 20 percent over Reynolds' data.

TOTAL LOGGING COST PER M B.F. BY TREE SIZE

It is recognized in appraisal work that not all logging costs can be assigned on a tree-size basis. However, since the basic data for determining average tree size are collected while cruising and marking trees for sale, full advantage should be taken of this information to make a more realistic and accurate appraisal.

There are several factors affecting logging cost which are essentially independent of tree size. These factors include: weather, which in turn affects both travel time and work time; accessibility, including access to the sale area and to the trees; road construction cost and length of haul; supervision; and finally, a margin for profit and risk. Since these factors are not directly assignable to tree size, they will be added where appropriate in the following set of costs (tables 5a, 5b) for mechanized mountain logging under a selected range of conditions.

It is assumed that power saws, tractors, and trucks will be used to good advantage by experienced workers, under the normal range of operating conditions found in this area. An indication of the spread of costs for each operation will be found under the separate columns headed easy and hard chance, as shown in tables 5a and 5b.

Although a range of conditions is covered by these average costs, the range is by no means complete. Consequently, an appraiser or operator who uses the data will have to exercise judgment in applying them to his specific case. Thus, while time and costs are shown for both pine and hardwoods, costs for mixtures will have to be interpolated.

Delays due to bad weather and walking to and from the job were not included in the time study or in table 5. Some of this extra time is discussed in the various text sections, e.g., 8 percent for log making, 20 percent for skidding. For convenience a single average figure of 15 percent could be added to total costs in table 5 before computing profit and risk. If logging costs are desired for a short job during the winter months, then all costs shown should probably be increased by one-third to one-half because of slower travel time and more difficult working conditions in the woods.

As the tree size increases, costs go down, at least within the size range sampled in this study. If variable costs only, including felling, skidding, and loading, are considered, dollar costs per M b.f.

Table 5a.--Logging time and cost per M b.f. for selected tree sizes, methods, and distances

Tree d.b.h. (Inches)	Power felling and bucking[1]						Skidding (D4 tractor)[2]				Loading[3]	
	Pine or soft hardwoods			Hard hardwoods			3 chains		30 chains		1 M b.f.	
	Time	Easy chance	Hard[4] chance	Time	Easy chance	Hard[4] chance	Time	Cost	Time	Cost	Time	Cost
	Man-hours	-- Dollars --		Man-hours	-- Dollars --		Crew hours	Dollars	Crew hours	Dollars	Crew hours	Dollars
12	2.50	3.75	7.50	4.0	6.00	12.00	.54	5.15	1.37	7.00	.69	3.05
16	1.70	2.55	5.10	2.9	4.35	8.70	.32	3.40	1.10	5.60	.45	2.05
20	1.30	1.95	3.90	2.3	3.45	6.90	.20	2.65	.94	4.80	.37	1.60
24	1.10	1.65	3.30	1.9	2.85	5.70	.16	2.20	.79	4.00	.31	1.35
30	.95	1.40	2.80	1.6	2.40	4.80	.13	1.70	.59	3.00	.27	1.15
36	.90	1.35	2.70	1.4	2.10	4.20	.07	1.20	.44	2.25	.24	1.05

1/ Time read from curves shown in figure 1. Hourly rate of $1.50.
2/ Costs read from figure 4. Time derived by dividing costs by hourly rate of $5.10.
3/ Loading time and cost are from table 3. Hourly rate of $2.75, but dollar column includes truck standby cost at $1.65 per hour.
4/ Hard chance costs are twice the easy ones and are for use under such severe logging conditions as steep rocky areas, or those covered with dense laurel.

Table 5b.--Total cost per M b.f. for selected tree sizes, methods, and distances

(In dollars)

Tree d.b.h. (Inches)	Cost of felling, bucking, skidding, and loading				Road bldg. & hauling 1/ 2/		Total including 20-percent margin 3/			
	Pine or soft hardwoods		Hard hardwoods		Easy chance	Hard chance	Pine or soft hardwoods		Hard hardwoods	
	Easy chance	Hard chance	Easy chance	Hard chance			Easy chance	Hard chance	Easy chance	Hard chance
12	11.95	17.55	14.20	22.05	4.05	17.30	19.08	41.82	21.78	47.22
16	8.00	12.75	9.80	16.35	4.05	17.30	14.46	36.06	16.62	40.38
20	6.20	10.30	7.70	13.30	4.05	17.30	12.30	33.12	14.10	36.72
24	5.20	8.65	6.40	11.05	4.05	17.30	11.10	31.14	12.54	34.02
30	4.25	6.95	5.25	8.95	4.05	17.30	9.96	29.10	11.16	31.50
36	3.60	6.00	4.35	7.50	4.05	17.30	9.18	27.96	10.08	29.76

1/ Easy road building cost is $600 for 1 mile. This sum divided by the cut (600 M b.f.) equals $1.00 per M b.f. Cost of a hard-chance road for 2 miles is $3000, or $5.00 per M b.f.

2/ Easy haul cost based on 1 mile woods road plus 5 miles highway ($3.05 total) plus $1.00 for road building. Hard haul cost based on 4 miles woods road plus 20 miles highway ($12.30 total) plus $5.00 for road building.

3/ Profit margin includes allowance for supervision.

for 24-inch trees average half as much as those for 12-inch trees regardless of species, and costs for 36-inch trees are only one-third those for 12-inch trees. These cost relationships are graphically illustrated in figure 7. Tree d.b.h. has an even greater effect on hand-logging costs than on machine-logging costs.

Detailed logging-cost information by tree size has another important application in addition to stumpage appraisals. In order to predict the earning power of standing trees of known growth rate, and the size at which they are financially mature, the forest manager needs to know among other things the cost of conversion for different tree sizes. The information presented here will provide the conversion-cost data needed in financial maturity computations.

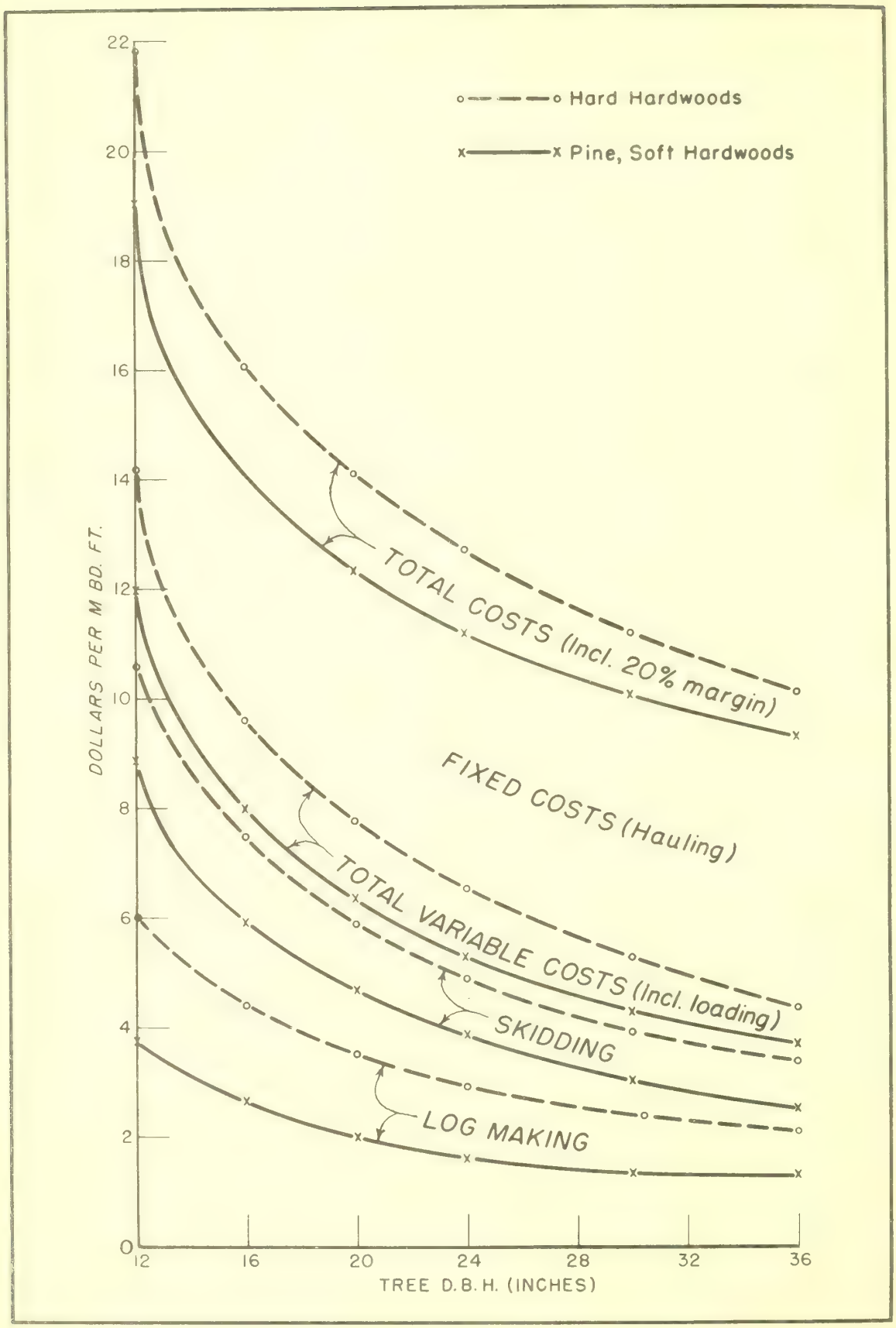


Figure 7.--Power logging costs per M b.f. by tree size. Based on easy-chance data, tables 5a and 5b. Skidding distance, 3 chains.

SUMMARY

In the log-making phase of this study it was shown that the power saws enabled men to produce logs in one-third the time required for hand tools, and at one-half the cost. These savings hold for both pine and hardwoods, and for most diameters. Tables and curves of time and cost per M b.f. are shown for various tree sizes, for two species groups, for both hand and power methods.

Skidding time per M b.f. is determined chiefly by load size and secondarily by distance traveled, for all skidding methods. In team skidding, the number of logs, species group, and slope are also important factors. As a general rule, teams should not be required to skid trees averaging 16 inches d.b.h. or larger and they should not skid more than 15 chains (1000 feet), except on slopes over 50 percent, where tractors are unsafe and inefficient. Cost tables and diagrams for both team and tractor logging for selected tree sizes and distance are presented.

The skidding phase of this study emphasizes the desirability and economic necessity of loading to capacity, regardless of motive power.

Loading time per M b.f. with power equipment is determined largely by number of logs per load and board-foot volume of load. Tables of loading time and cost for various load volumes and tree sizes are presented. Hauling time and costs for woods and highway classes of roads are also shown.

Variable costs (log making, skidding, and loading) will usually comprise from one-fourth to three-fourths of the total, depending largely on the road-building and hauling costs. Detailed tables show the components of total logging cost by tree size for mechanized operations under easy and difficult working conditions. Total variable costs for 36-inch trees are only one-third and for 24-inch trees only one-half the costs for 12-inch trees.

Intelligent supervision is a necessity particuliarly in mechanizing logging. The use of large crews in log making and skidding tended to reduce the output per man. Proper work planning will insure full utilization of time by both men and machines. This combination will make logging both easier and safer for the worker as well as saving money for the operator.

Brief statements on road construction costs and sawmilling requirements by tree size are given in the appendix section. In addition the appendix contains tables of hourly equipment rates for sawing, skidding, loading, and hauling. These may be used in recomputing hourly rates where costs are different from those given.

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APPENDIX

Road-Construction Costs

Mountain roads suitable for truck travel on all but snowy or rainy days and immediately thereafter can be built for as little as $300 per mile in favorable locations. Such locations include those with moderate slopes (up to 20 percent), practically no drainage problems, and no rocks or a few loose ones per mile. Construction costs per mile for mountain truck roads will average closer to $600 or $700 per mile, however. Surfacing, even with local creek gravel usually costs an extra $1000 to $1500 per mile. Road-construction costs increase rapidly as the slope increases and especially as the amount of solid rock increases, until a feasible limit of about $2500 per mile is reached for unsurfaced graded truck roads. Somewhere near this point road construction costs are prohibitive and direct skidding or cable logging are the only alternatives.

On the Fernow Experiment Forest, near Elkins, West Virginia, skid roads suitable for tractor and sulky use, but too narrow for truck use, are built for approximately $80 to $250 per mile (10).

Sawmilling

The information in this section, as in the one on roads, is included for the benefit of appraisers and to complete the picture of logging and milling costs.

A recent study made by the Forestry Relations personnel of the Tennessee Valley Authority (4) included 58 mills in three size classes well distributed over the Tennessee Valley. In the small mills (those with 4 men and 65 h.p. or less) each of the variables studied (species, log diameter, and log length) were important. In the medium-size mills (those with 6 men and 85 h.p.) species differences were less important, probably because of an abundance of power. Lost time is very important to all classes of sawmills, as pointed out by Darwin and Thurmond (4).

The following table of time and cost per M b.f. is based on the TVA study, and data are for medium-size mills sawing hard hardwoods.4/ Time for lumber grading, stacking, or hauling is not included in the man-hours shown below. The cost data are derived by multiplying the crew hours by the hourly rate of $6.30 for a 6-man crew.

Table 6.--Sawmilling time-and-cost data per M b.f., by tree size

Tree d.b.h. (Inches)	Av. log d.i.b.	Crew hours per M b.f.1/	Milling cost per M b.f.1/	Total cost per M b.f.2/
	Inches	Hours	Dollars	Dollars
12	9	2.3	14.50	31.00
16	12	1.7	10.70	24.30
20	15	1.5	9.50	21.10
24	18	1.1	6.90	17.50
30	21	1.3	8.20	20.00

1/ Milling time only. Time and cost data from "Circular Sawmills in the Tennessee Valley Region" by Paul H. Lane. Forest Products Research Society Proceedings 5: 17-23. May 1951.

2/ Difference between milling cost and total cost consists of capital, materials, and overhead--including handling.

4/ In this study they found that pine and soft hardwoods cost about 10 percent less per M b.f. to saw than do hard hardwoods.

Table 7.--Computation of total hourly cost for two-man crosscut crew

	Hourly cost
Investment	
2 axes ($10.00), 2 pair wedges ($5.00), 1 hammer ($5.00), 2 crosscut saws ($20.00) = $40.00	
Fixed cost per hour (200 days X 8 hours = 1600 hours)	
Depreciation $40.00 ÷ 1600 hours	$ .025
Maintenance[1]	.075
Subtotal	$ .100
Operating cost per hour	
Wages, 2 men at $0.80	$ 1.60
Plus Soc. Sec., Workmen's Comp., etc. at 10%	.16
Subtotal	$ 1.76
Total cost per crew hour	$ 1.86
Cost per man-hour (rounded)	$ .95

Table 8.--Computation of total hourly cost for two-man power-saw crew

	Hourly cost
Investment $450 for 5 h.p. 40" saw, gas can, files, etc.	
Fixed cost per hour (200 days X 8 hours = 1600 hours)	
Interest at 6% on 1/2 of investment ÷ 1600 hours	$ .01
Depreciation of $450 ÷ 1600	.28
Maintenance, parts and labor[2]	.67
Insurance or risk[2]	.02
Subtotal	$ .98
Operating cost	
Gas, oil, wedges,[2] etc.	$ .24
Labor, 2 men at $0.80 + 10% (Social Security, etc.)	1.76
Total cost per crew hour	$ 2.98
Cost per man-hour (rounded)	$ 1.50

1/ Details of maintenance are from F. C. Becker, Jr. (1).
2/ Based on data from R. R. Reynolds (7).

Table 9.--Computation of total hourly cost for team and teamster

Investment		
Team and harness	$300	
Average life, 4 years. Annual depreciation	75	
Fixed cost (200 days X 8 hours = 1600 hours)		Hourly cost
Depreciation of $75 ÷ 1600 hours		$ .05
Interest and taxes		.01
Subtotal		$ .06
Operating costs		
Annual feed bill $1100, shoes $50, medicine $25 harness repair $50, tool replacement $50.		
Subtotal $1300 ÷ 1600 hours		$ .80
Teamster at $0.90 plus 10% Social Security, etc.		.99
Subtotal		$ 1.79
Total cost		$1.85

Table 10.--Computation of total hourly cost for power skidder-loader operator, and helper

	Skidding and loading	Loading only
Investment		
Truck, drum, motor, tongs	$ 2000	
Trade-in value after 6 years (junk)	200	
Amount to be depreciated in 6 years	$ 1800	
	Hourly cost	
Fixed cost		
Yearly depreciation of $300 ÷ 1600 hours	$ .19	
Int. at 6% (average investment), taxes	.06	
Subtotal	$ .25	$ .15
Operating cost--skidding		
1 cable 5/8 in. X 900 ft. at $285, chokers and hooks at $6 X 6 per year = $320 ÷ 1600	$ .20	$ .15
Fuel-gas at $0.30 per gal. X 1-1/2 per hour	.45	.30
Oil and grease	.08	
Repairs and labor (estimated)	.17	.15
Subtotal	1/ .90	.60
Labor		
Operator at $1.00, helper at $0.80 + 10% for Social Security, etc.	$ 1.98	$ 1.98
Total hourly cost	$ 3.15	$ 2.73
Total man-hour cost (rounded)	$ 1.60	$ 1.35

1/ Costs may vary ± 15 percent for hard or easy skidding chances.

Table 11.--Computation of total cost per hour and per mile for light logging truck (such as Ford or Chevrolet) and driver

Investment	1-1/2 ton	2 ton
Truck only ($630 for tires included below under running cost)	$ 1670	$ 2022
Locally made bed	100	100
Subtotal	$ 1770	$ 2122
Trade-in value after 2 years	1370	1620
Amount to be depreciated in 2 years	$ 400	$ 500
Fixed cost	**Annual**	
Int. at 6% on 1/2 investment	$ 85	$ 100
License, North Carolina	160	175
Taxes, North Carolina	20	25
Insurance or risk at 4% of cost[1/]	95	110
Total	$ 360	$ 410
	Daily	
Daily cost at 200 days	$ 1.80	$ 2.05
Daily depreciation at 350 and 400 days[1/]	3.45	3.40
Daily driver at $0.90 + 10% Social Security, etc.	7.90	7.90
Total daily cost	$ 13.15	$ 13.35
Hourly cost (8 hours)	1.64	1.67
Average	$1.65	

Running cost[1/] per mile	Pavement	Log road
Tires	$ .06	$ .12
Gas and oil	.03	.07
Repairs and labor	.03	.06
Total	$ .12	$ .25

1/ Based on data from R. R. Reynolds (7).

Table 12.--Computation of total hourly cost for tractor and operator

Investment	D2	D4	D6
Tractor f.o.b. Asheville (ready to go)	$ 4810	$ 6300	$10050
Winch f.o.b. Asheville (no cable)	1240	1475	1825
Subtotal	$ 6050	$ 7775	$11875
Dozer blade and controls	2000	2325	2725
Total	$ 8050	$10100	$14600
Trade-in value after 5 years	1860	2250	2500
		Hourly cost	
Fixed cost, tractor and winch[1/]			
Depreciation 10,000 hours	.619	.785	1.21
Int., ins., taxes	.183	.237	.354
Total fixed	.802	1.022	1.564
Operating costs, 1953 average[1/]			
Fuel at $0.14 per gal. (no tax)	.224	.280	.434
Gas for starting	.030	.030	.030
Oil	.034	.036	.050
Grease at $0.15 per pound (incl. winch)	.026	.041	.057
Cable for winch	.155	.199	.265
Repairs and labor (incl. winch)	.508	.649	1.024
Total variable	.977	1.235	1.860
Total fixed + operating cost (average)	1.78	2.26	3.42
Easy work = - 15%	1.50	1.90	2.90
Hard work = + 23%	2.20	2.80	4.20
Operator at $1.00, $1.25, $1.50 plus 10% for Social Security, etc.	1.10	1.38	1.65
Helper at $0.75, $0.85, $1.00 plus 10% for Social Security, etc.	.83	.94	1.10
Total (rounded)	1.90	2.30	2.75
Total all costs			
Average	3.30	4.55	6.15
Easy	3.00	4.20	5.65
Hard	3.80	5.10	6.95
Added rate when blade is used	.22	.24	.26

1/ Data from Asheville agency Caterpillar Tractor Co., January 1953.

STATION PAPER NO. 31 NOVEMBER 1953

SAWMILL AND LOGGING RESIDUES IN THE SOUTH CAROLINA PIEDMONT

Problems and Methods of Salvage

by

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FOREWORD

Recently there has been much interest in the possibilities of utilizing lumber waste products, such as slabs, edging strips, and logging residues, in the manufacture of paper and hardboard. However, salvage operations of this kind are complicated in the Southeast by the fact that three-quarters of our lumber is produced at several thousand scattered, small sawmills. The research reported here was an attempt to analyze the problems of salvaging pulpable material from the lumber operations in a typical area of the Piedmont and to appraise the feasibility of various methods for preparing, assembling, and transporting it. The report is published as a contribution under Title II of the Research and Marketing Act of 1946.

The author takes this opportunity to acknowledge the help of Dr. Carl H. Stoltenberg and Mr. William H. B. Haines, who worked with him. He also wishes to thank the many farmers, other forest landowners, lumbermen, pulpwood dealers, and pulpwood producers whose cooperation made the project possible.

COVER PHOTO

The sawmill has moved on. Fifty-nine percent of slabs and edgings in the study area are given away or left to rot.

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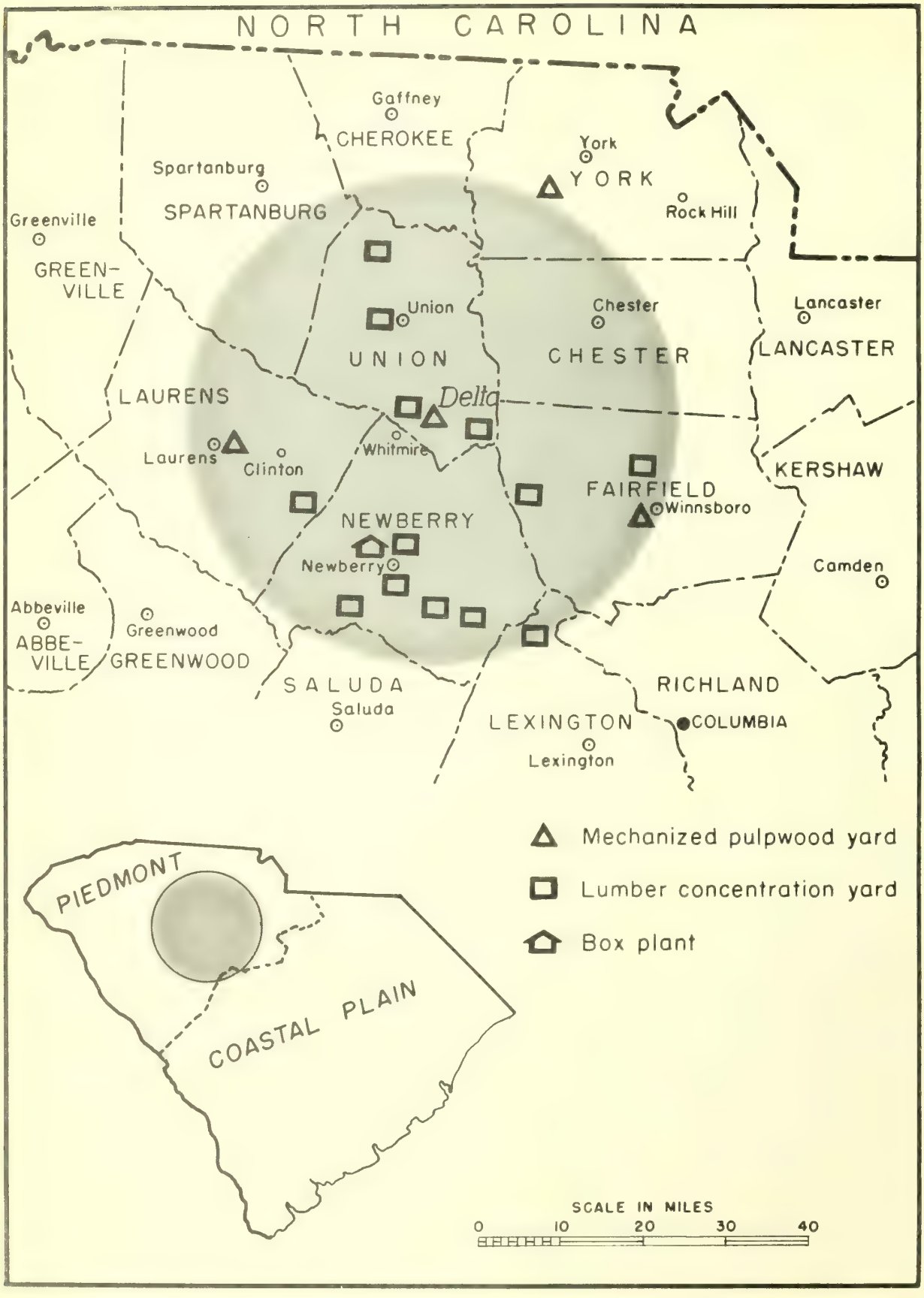

The Delta area of South Carolina. Circle is a 30-mile radius.

SAWMILL AND LOGGING RESIDUES IN THE SOUTH CAROLINA PIEDMONT: PROBLEMS AND METHODS OF SALVAGE

by

A. S. Todd, Jr.

A thousand board feet of dressed pine lumber contains 61 cubic feet of wood. However, to obtain this volume of finished product the lumberman must cut approximately 200 cubic feet of sound standing timber. Of the volume lost, some 20 percent is left in the woods as tops and broken trees; 60 percent is in slabs, edging strips, end-trims, and sawdust at the mill site; while the remaining 20 percent is largely planer shavings. At the present level of lumber production in the Southeast, the output of solid residues alone is equivalent to nearly 7 million cords annually (fig. 1).

Figure 1.--For every thousand feet of lumber sawed, more than a cord of solid residue is produced.

As time passes, ways are usually found to convert more and more of the waste products of manufacture to useful purposes. In the case of southern lumber residues, the trend seems to have been in the opposite direction. Years ago, when most mills were steam-powered, large quantities were consumed on the spot as fuel, but the adoption of gasoline and diesel power has largely eliminated this use. Today, sawdust and shavings ordinarily rot on the ground or are burned to reduce the fire hazard. Solid mill residues, such as slabs, are still a main source of firewood in rural areas, but even this use has declined. The greater availability of electricity, gas, and oil has so reduced the demand that slabs are given away more often than they are sold.

The only type of residue that has gained utility is topwood. Very little of it was ever salvaged until recently, but enough is now being cut into pulpwood to give it a small but recognized market value. Currently, the paper and pressed-board makers are greatly interested in the possibilities of utilizing sawmill slabs, and edgings as well.

Mill residues of one sort or another were first pulped in the West, where individual lumber and veneer plants were large enough to provide substantial amounts of suitable material and to warrant the installation of elaborate log-barking equipment. Since then, the pulping of mill residues has grown spectacularly in that region. In 1951, about a million cords were converted to pulp. This volume was supplemented by 400 thousand cords of cull trees and other logging leftovers to fill 30 percent of the year's pulpwood requirements. Southeastern pulpmills, by contrast, used only some 100 thousand cords of mill residues, largely veneer cores, even though their total consumption of pulpwood was 70 percent greater than that of the West.

A primary reason for the delay in following the western example is the small size of the average sawmill and the virtual absence of lumber-producing centers. Until now, the smallest practical log barkers have required a minimum daily output of 30 thousand board feet to justify their installation. There are probably not 50 sawmills in the Southeast that meet this specification, and 70 percent of our lumber production is from mills that average 12 thousand board feet or less a day. Many are portables whose relative inaccessibility and frequent moves pose a complex problem of wood assembly in addition to the problem of bark removal.

The research reported here was an attempt to analyze the problems of salvaging plant and logging residues from the preponderantly small sawmills of a typical lumber-producing area, and to investigate the comparative efficiency and general practicability of various possible methods of preparing, assembling, and transporting this material.

WHY PULP LUMBER RESIDUES?

There are a number of good arguments for salvaging these lumber residues as a substitute for pulpwood from live trees. The one of most general interest is the conservation argument. In this region, it is especially convincing.

Sawtimber drain exceeds sawtimber growth in most parts of the Southeast. Aside from reducing the volume of sawtimber cutting, the only way of correcting the unfavorable balance is to grow more trees to larger size. Unfortunately, the current trend is in the opposite direction. As big trees become scarcer, lumbermen cut to smaller and smaller diameters. At the same time, expansion of the pulp industry threatens to reduce the number of trees allowed to reach profitable sawtimber size.

This situation is to the disadvantage of timber users and growers alike. The lumber industry finds itself turning out an ever-poorer grade of product at mounting cost, with consequent danger of losing markets to other regions or substitute materials. Furthermore, the size distinction between sawlog and cordwood stumpage is disappearing, so that sawmills frequently outbid pulpwood producers for timber of the size and character formerly considered suitable only for pulpwood. As for the landowner, intensified competition among timber buyers and a high level of stumpage prices seem to be working to his immediate benefit. In the longer run, however, he faces the possible loss of quality markets as timber resources become less and less adequate to support them.

Eventually, we may be able to provide all the timber of every size we need by building up the stocking and general productivity of the forests. For the immediate future, the most effective measure would appear to be fuller utilization of the wood now available. This can be accomplished in two related ways: (1) by substituting tree species and grades in surplus supply, wherever possible, for those on the critical list, and (2) by integrating wood use so that one industry uses material discarded by another.

If fuller utilization can be achieved, timber resources and markets will be safeguarded, and trees or portions of trees for which there is little present demand will become salable. However, any worthwhile progress in this direction must depend on the cooperation of lumber and pulp manufacturers, for between them they consume 75 percent of all the timber cut.

Aside from its potential value as a conservation measure, the pulping of lumber residues offers specific and practical benefits to the individuals and companies involved. Sawmill residues, for instance, offer pulp companies a more stable wood source than they now enjoy. Full-time commercial sawmills operate more consistently and are less affected by weather than pulpwood crews. This in itself is a strong recommendation.

To avoid shutdowns due to seasonal shortages of wood, southeastern pulpmills each carry up to $1,000,000 or more of wood inventory. To prevent large losses from deterioration of this inventory, some $100,000 a year is spent in turning it. Even so, the deterioration is sufficient to cause a 5-percent loss of pulp yield, and periodic gluts and famines of wood have not been entirely eliminated. Supplementing the regular wood with sawmill residues would tend to smooth out seasonal fluctuations, and untapped slab piles could serve as a reserve source in place of a portion of the woodyard inventory. In this way, both carrying charges and deterioration losses would be reduced.

Among the lumbermen, there are many who would be interested in selling their residues, and the added income is not their only incentive. The more thoughtful are genuinely disturbed by the quantities of unused material they create, and the disposal of sawdust, slabs, and strips has been a serious problem ever since the disappearance of steam boilers. The solids are the most troublesome. Sawdust can be conveyed mechanically, but the slabs and strips must be removed and piled by hand. At portable mills, where space is ordinarily at a premium, more labor is expended on the waste products than in handling the lumber (fig. 2).

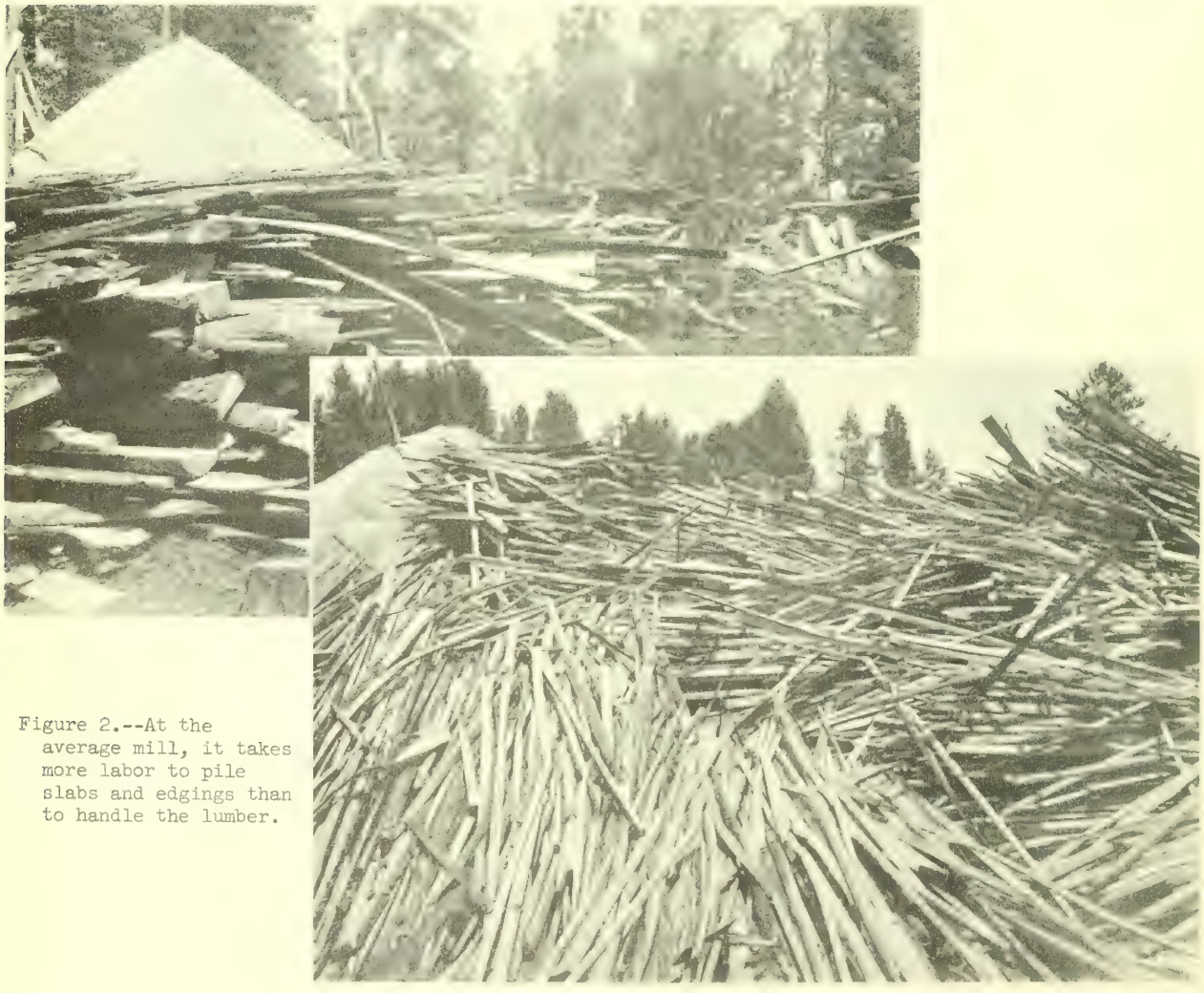

Figure 2.--At the average mill, it takes more labor to pile slabs and edgings than to handle the lumber.

If slabs could be fed directly through a chipper and into a parked trailer as they come from the saw, some operators could nearly afford to give away the resulting chips. However, if the slabs could be made to show a profit, they might mean the difference between operating or shutting down in times of depressed lumber prices. At any time, they would provide a competitive advantage in bidding against straight lumber manufacturers for stumpage.

A profitable market for mill residues would also benefit farmers and other timberland owners, since stumpage prices would soon reflect the added utilization. The conversion of logging residues to pulpwood results in a double gain. Not only does timber take on extra value, but the cutover area is left in more accessible condition and with a reduced fire hazard.

SELECTION OF A STUDY AREA

In choosing an area for this study, the principal requirements were (1) that it be small enough to permit a fairly detailed survey of the nature, quantity, and location of its sawmill and sawmill logging residues; (2) that it represent as nearly as possible the area a pulpmill or its contractor might select as a practical operating unit for wood procurement purposes; and (3) that the logging and sawmilling conditions be typical of an extensive region in the South. The area selected was a circle of 30-mile radius centered on Delta, Union County, South Carolina, a small rail station and siding in the Piedmont.

Included within the 30-mile circle are all or parts of 11 counties: 2,827 square miles, 1,718 or 61 percent of which is commercial forest. About one-half of the commercial forest is on farms, and most of the remainder in small private holdings. The practicability of the area as a procurement territory is evidenced by the presence of two mechanized pulpwood yards within and two more just outside the circle. In 1951, pulpwood production probably totaled 214 thousand cords. Lumbering is also in active progress, and local operations are typical of the "roofer belt," which extends along the southern piedmont from Virginia through Georgia.

LUMBERING IN THE DELTA AREA

Once a suitable area had been selected, the first task was a complete canvass of logging and sawmill operators. This was done during April and May 1952.

The canvass showed 147 operating sawmills and 6 full-time commercial loggers in the Delta area. Lumber production during 1951 totaled 81.4 million board feet, of which 66.8 million or 82 percent was pine (table 1). Construction lumber was the chief product.

Table 1.--Lumber production by species, 1951

Species group	Production	
	Thousand bd. ft.	Percent
Southern pines	66,797	82.0
Yellow-poplar	6,742	8.3
Sweetgum	2,991	3.7
Other soft-textured hardwoods	915	1.1
Oaks	3,355	4.1
Other hard-textured hardwoods	640	.8
All species	81,440	100.0

The sawmills are of three predominant types: board mills, structural dimension mills, and "country" mills that saw lumber for home or farm use. Because of the proximity of North Carolina furniture centers, there are also a few specializing in hardwood dimension stock. The numbers of mills by type and their 1951 output were as follows:

	Million bd. ft.
69 dimension mills	49.4
23 board mills	20.7
55 other mills	11.3

There are no large sawmills in the Delta area. One with an expected capacity of 30 thousand board feet per day was under construction at the time of the canvass, but probably none of those in operation could saw half this amount. Production is further limited by the fact that many of the mills operate only part time. For instance, 45 of the 147 mills in the area were custom or farm-owned and sawed but a few days a year. In 1951 there were only 34 that produced as much as a million board feet, and they accounted for 60 percent of the year's output. Most of these larger-producing sawmills were portables (table 2).

The Delta area has few remanufacturing plants and no cities. Consequently, most of the lumber produced there is shipped out. The task of assembling this lumber from the many small sawmills, seasoning and surfacing it, and preparing it for shipment is handled by 12 concentration yards equipped with trimmers and planers. They receive the rough green lumber as fast as it is sawed and, in some cases, pay for each truckload individually. Thus, mill operators need not carry inventories and are able to stay in business with a minimum of working capital. Yards also provide help in financing timber and equipment purchases.

Table 2.--Sawmills by 1951 lumber production

Production class	Mills	
Thousand bd. ft.	Number	Percent
Less than 200	61	41.5
200 - 399	14	9.5
400 - 599	14	9.5
600 - 799	13	8.8
800 - 999	11	7.5
1000 - 1199	6	4.1
1200 - 1399	9	6.1
1400 - 1599	10	6.8
1600 - 1799	3	2.1
1800 - 1999	4	2.7
2000 - 2199	1	.7
2200 - 2299	1	.7
All classes	147	100.0

Methods of obtaining green lumber vary from yard to yard, but only a few yards depend entirely on purchases from independent sawmills. Some own and operate mills of their own, others buy timber and contract the logging and sawing. There are examples of all these arrangements in the Delta area, and nearly 20 percent of the mills ordinarily operate under contract.

The typical portable sawmill has an inserted-tooth circular headsaw and is powered by a diesel engine. It may or may not possess an edger and has neither a trimmer nor a cut-off saw. Mill crews range from five to nine men, woods crews from five to seven. Felling and bucking are by power saws, and the logs are bunched by horses or mules. Transportation to the mill may be by truck or by a wheel-tractor and high-arch log cart. Where a truck is used, it is ordinarily loaded from the ground with a crosshaul. Crawler tractors and power skidders are occasionally seen, but they are not common.

At the time of the sawmill canvass, 104 timber tracts were in the process of logging, and there were portable sawmills on 98 of them (fig. 3). All the other active mills were stationary. The 104 tracts totaled 8,100 acres and were estimated by the operators to contain 17.3 million board feet. Individual acreages ranged from 10 to 500, averaging 77. The board-foot cut per acre ranged from 500 to 10,000 and averaged 2,400. The indication is that about 450 timber tracts, or 30,000 acres, are cut over annually by lumbermen. In addition, an unknown but certainly sizable volume is cut in "patch" logging, principally by farmers getting out logs to be custom-sawed.

The canvass, in addition to providing a basis for the preceding description, was the first step in a survey to find out how much chippable sawmill and sawmill logging residues are produced annually and seasonally by species, where they are located, and in what concentration at each location. Succeeding steps during the summer of 1952 were (1) a sample of logging operations on which to measure logging residues, and (2) a sample of sawmills at which to obtain data needed for estimating mill residues. These samples were designed to provide ratios of waste output per thousand board feet that could be applied to reported volumes of lumber production.

The principal purposes of the canvass were to determine the 1951 lumber production by quarters and species for each sawmill and, in the case of portable mills, to obtain the operators' estimates of the volumes to be sawed at the sets where the mills were found. For sawtimber tracts in the process of being logged, acres to be logged as well as estimated cuts were obtained. Information was also recorded as to type of operator (independent, contract, custom, or private) and chief product (e.g., pine boards, pine dimension), either of which might influence utilization. Sawmill operators were further questioned as to what use, if any, they made of their slabs, edgings, and trim. Finally, all the sawmills and timber tracts were spotted on county highway maps and identified by code numbers.

In seeking information on current tracts and mill sets, it was assumed that their locations and concentrations of residues represented the pattern likely to prevail in the Delta area for several years. Even though most operators move every few weeks, the geographic distribution of lumbering activities remains fairly constant. For instance, comparisons of the 1952 geographic distribution of sawmills with that of a 1947 canvass[1/] shows little change for the five years intervening. Therefore, the 104 tracts and 99 mill sets were adopted as typical in location, size, and residue volume of the tracts and sets that might be found at any time in the near future. They will be referred to in this report as the May 1952 timber tracts and sawmill sets.

From the loggers found during the canvass, a random sample of 22 operations was drawn on which to measure the usable volumes of topwood and broken trees produced per thousand board feet of sawlogs. At each logging site, 24 trees were measured as they were felled and bucked. Logs were scaled according to the International 1/4-inch Rule; tops and broken trees were scaled in cubic feet by standard 63-inch pulpwood lengths to a variable minimum diameter of approximately 4 inches

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1/ A canvass by the Forest Service in cooperation with the Department of Commerce, Bureau of the Census, for the 1946 Census of Lumber Production.

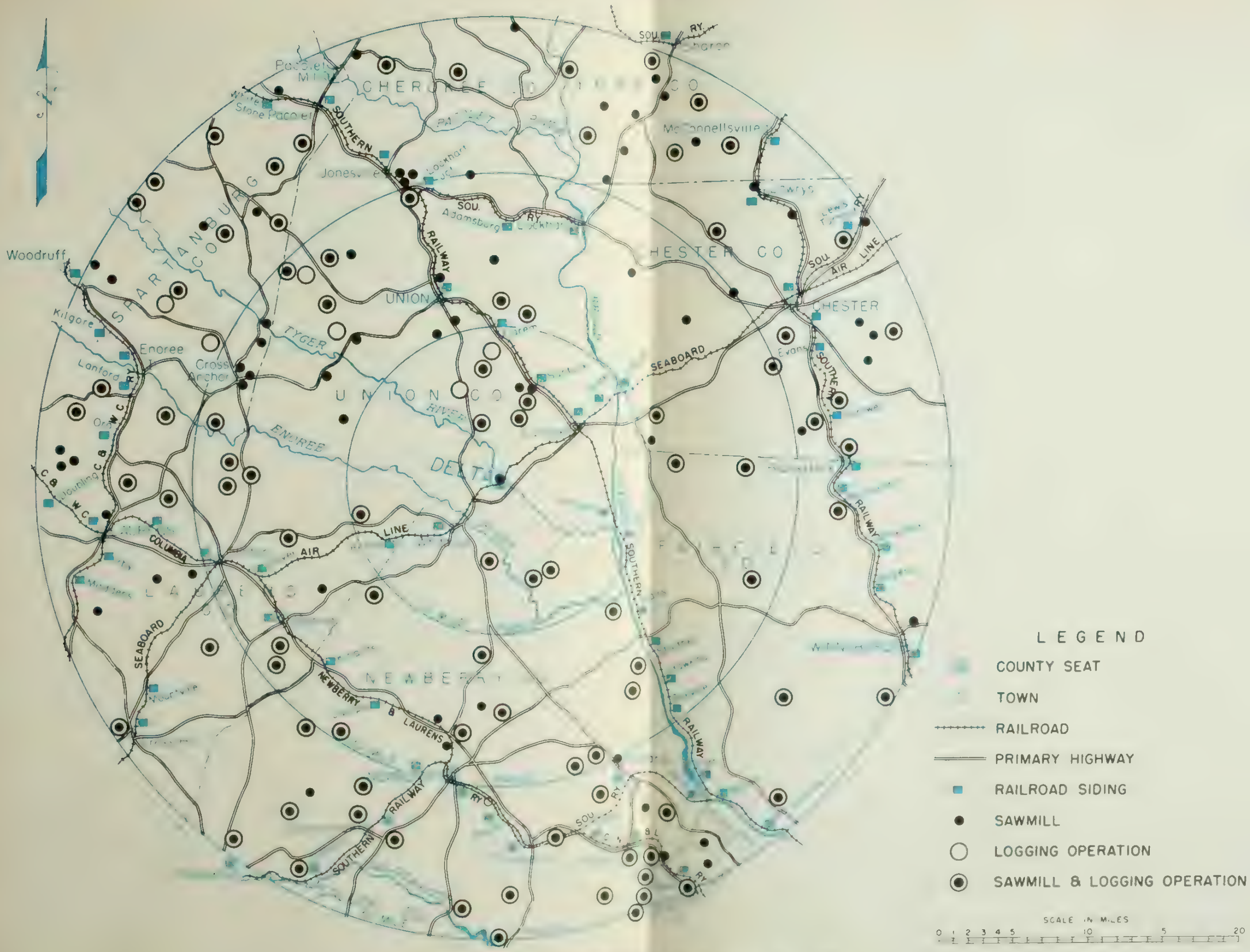

Figure 1.--Lumber[illegible] in the Delta area, May 1, [illegible].

inside bark. The final step was to measure the acreage from which the 24 trees had been cut. Cubic feet of logging residue (without bark) per thousand board feet was computed by species groups for each operation and for all operations together. These ratios were subsequently converted from a log-scale to a lumber-tally basis by applying average overrun and underrun data.

A second random sample was drawn, this time of 26 sawmills, at which to determine the distribution of the lumber produced and the overrun or underrun by log diameters. This was done by tallying the lumber from 50 consecutive logs at each mill. Given the lumber distribution by log size, Carpenter's chippable waste factors[2/] could be applied to the reported lumber production of all the Delta sawmills. The overrun and underrun data served to convert the logging residue factors from a log-scale to a lumber-tally basis so that they, too, could be applied to reported volumes of lumber production.

Sawtimber Tops and Broken Trees

With two exceptions, the sample logging operations were in stands being cut primarily for pine. The residue ratios (cubic feet of residue per thousand board feet) for the individual operations showed a negative correlation with the board-foot cut per acre--the heavier the cut, the less residue per thousand. This correlation was weak for the lighter cuts, several of which were partial cuttings, but strong for the heavier cuts, which were all clear-cuttings. The regression equation for all species combined is $Y = 41.13 + .00285X$ where Y is cubic feet of logging residue per thousand board feet and X the cut per acre in thousands of board feet. The regression coefficient .00285 is significant at the 1-percent level. Therefore, when the cuts per acre for individual tracts are known, the regression offers a closer approximation of the true residue ratios than an average.

To take advantage of this relationship, each of the 104 timber tracts in the Delta area was sampled to estimate its average cut per acre. Stump tallies of 10 one-fifth acre plots were made on each tract after the completion of logging and provided estimates within ±20 percent in most cases. The regression values applied to the tracts were as follows:

2/ Carpenter, Roswell D. Amount of chippable waste at southern pine sawmills. U.S.D.A., Forest Service, Southern Forest Experiment Station Occasional Paper 115, Nov. 1950. "Chippable waste" was defined in this report as all slabs, edgings, and end-trim at least 1 foot long with the exception of thin, ribbon-like pieces of edging strips.

Cut per acre (M board measure)	Usable logging residues per M board measure (Cubic feet of wood)
1	38
2	35
3	32
4	30
5	27
6	24
7	21
8	19
9	16
10	13

A similar relationship for pine alone also proved highly significant, although not significantly different from that for all species. Having an excellent estimate of the over-all cut per acre on the 104 tracts, the average residue ratio for pine was computed by regression. Regressions for hardwoods were not significant, so the ratios for these species are merely weighted sample means. The resulting ratios and their standard errors by species group3/ are as follows:

Species	Usable logging residues per M board measure	
	(Cu. ft. of wood)	(Standard error)
Pines	31.1	± 4.7
Soft hardwoods	36.3	± 4.3
Hard hardwoods	35.5	± 7.9
All species	32.0	

These logging residue ratios take into account the average overrun and underrun at the 26 sample sawmills and can be applied, therefore, to reported lumber production. However, as previously noted, the Delta mills tend to specialize when sawing pine--some on boards and some on 2-inch stock. This, of course, affects the lumber out-turn. Dimension mills obtain 6 percent more yield from a given scale of logs than board mills; the "country" mills obtain 4 percent less. Thus, if the principal products represented by a volume of production are known, as they were in this case, the following residue ratios for pine can be substituted for the 31.1 average:

3/ Species included in the groups are (1) pines--loblolly and shortleaf; (2) soft hardwoods--mostly sweetgum and yellow-poplar with some soft maple; hard hardwoods--mostly oaks with some ash, elm, and river birch.

Mill type	Usable logging residues per M board measure (Cubic feet of wood)
Board mills	32.0
Dimension mills	30.2
Other mills	33.3

Once computed, all cubic-foot volumes of logging residues were converted to standard cords on the basis of 64 cubic feet of wood per rough cord.

Slabs and Edging Strips

Close cutting over a period of years has made large quality sawtimber extremely scarce in the Delta area. This and an abnormally active demand for 2 x 4's and strips have caused a marked reduction in the size of the average sawlog. Trees are now commonly utilized to a 5-inch top, and crooked or rapidly-tapering sections are bucked into lengths as short as 8 feet. Figure 4 shows the distribution of lumber production by log diameter at the 26 sawmills sampled for residues.

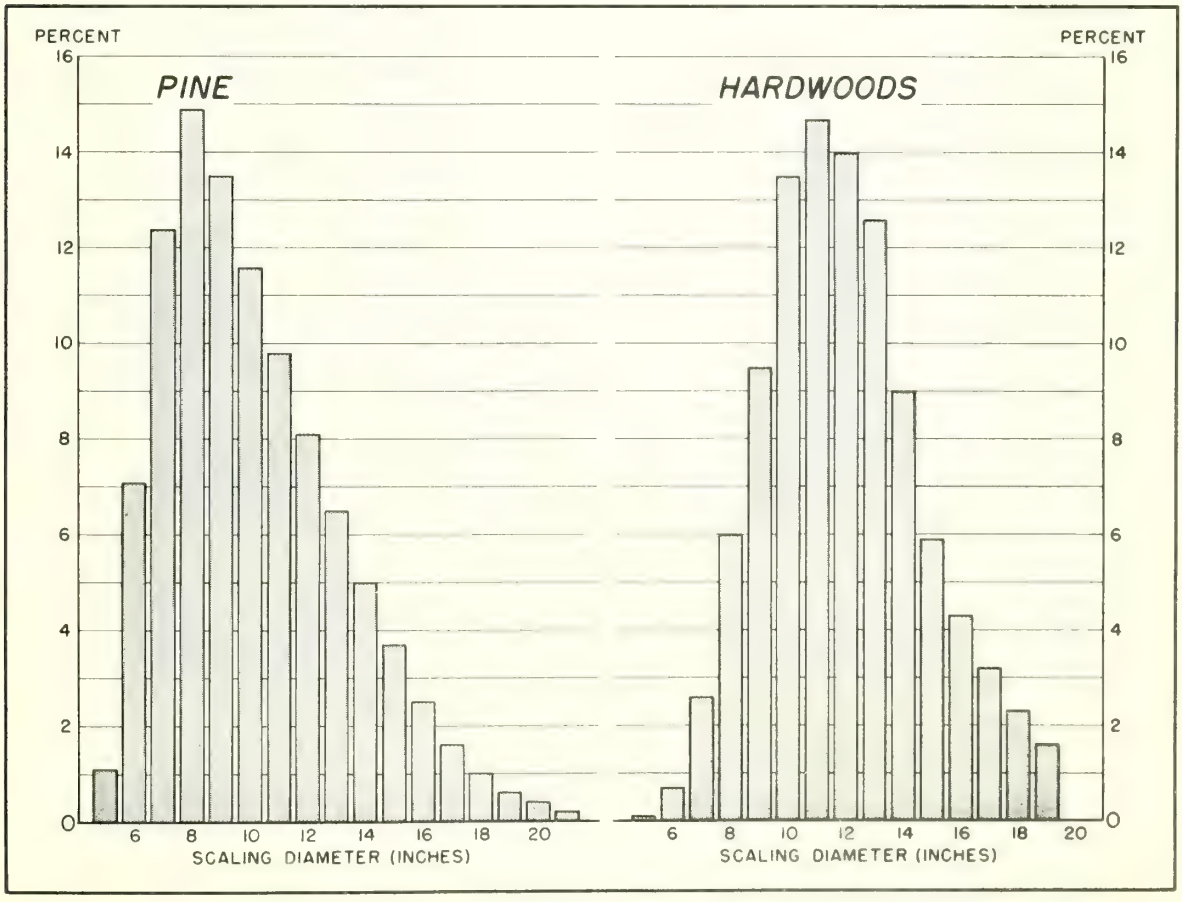

Figure 4.--Lumber production by species-group and log diameter.

Applying Carpenter's chippable waste factors (see footnote 2) to the sample-mill lumber production by log diameter provided average factors by species groups and products. During the process, these factors were adjusted to give chippable volumes in terms of equivalent cords of pulpwood-size round wood. In other words, according to the usage in this report, a "cord" of mill residue contains the same solid volume of wood as a cord of rough pulpwood. Thus, mill and logging residues are in comparable units.

The conversion to equivalent rough cords of round wood was on the assumption that an average cubic foot of green pine wood, when oven-dried, weighs 28.72 pounds (specific gravity .46 4/). A rough cord of pulpwood-size bolts was assumed to contain 78 cubic feet of wood.

The mill residue ratios applied to the reported 1951 lumber production in the Delta area were as follows:

Species and type of mill	Usable mill residues per M board measure (Standard cords with bark)
Pine--board mills	.65
Pine--dimension mills	.74
Pine--other mills	.78
Soft hardwoods--all mills	.58
Hard hardwoods--all mills	.46

Since Carpenter's factors are only for pine, their application to hardwoods is subject to some error. For sweetgum and yellow-poplar, the chief soft hardwoods, the error is probably not large, since these species have approximately the same form and specific gravity as pine and are sawed locally in much the same manner. In the case of oaks and other hard hardwoods, the residue estimates are likely to be conservative.

The residue ratios applied to the May 1952 portable mill sets were weighted averages derived from the ratios given.

4/ Anon. Weights of various woods grown in the United States. U.S.D.A., Forest Service, Forest Products Laboratory Tech. Note 218, Oct. 1952.

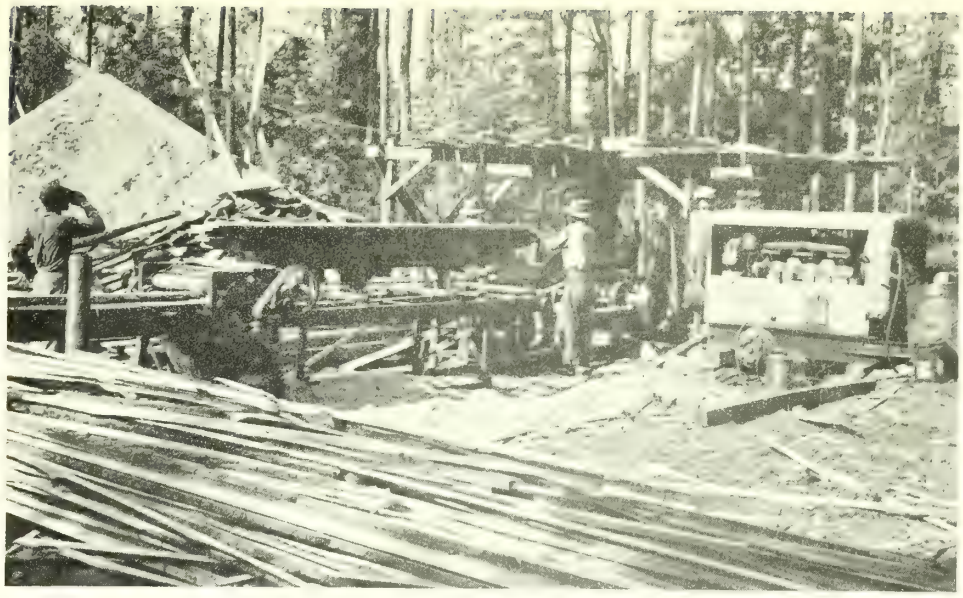

Figure 5.--This portable mill produces about 2,100 cords of pulpable residues a year.

Figure 6.--The Delta area produces over 200,000 cords of pulpwood a year. If all usable lumbering residues could be pulped, this cut might be reduced 43 percent.

RESIDUES AVAILABLE IN THE DELTA AREA

To gain some conception of what the residue ratios mean, it may be helpful to think of a typical Delta sawmill operating in a typical stand of timber (fig. 5). The mill has a daily output of 6,000 board feet; the average cut per acre is 2,400 board feet. A stand of this density yields about 34 cubic feet inside bark of pulpable topwood and broken trees per thousand board feet. Therefore, the logging produces 204 cubic feet or over 3 cords of this material every day. The chippable slabs and edging strips at the mill are equivalent to another 4 cords of round wood. Thus, this typical operation produces as a by-product as much pulpable wood per day as an average pulpwood crew (fig. 6).

Pulpwood production during 1951 in the counties of Chester, Fairfield, Laurens, Newberry, Spartanburg, and Union totaled 299,923 standard cords. Since one-half or more of the acreage of each of these counties lies within the Delta area, their rate of production should be representative of it. If so, the Delta area is one of the heavier pulpwood-producing areas in the South. Its 1951 production must have been in the neighborhood of 214 thousand cords, or nearly 0.2 cords per forested acre. Yet, if all the usable sawmill and sawmill logging residues could have been salvaged and pulped, they would have replaced 43 percent of this pulpwood.

The 1951 output of usable residues in the Delta area was estimated at 96,789 cords. Of the total, 40,595 cords or 42 percent was in tops and broken trees, the remaining 56,194 cords in slabs and edging strips (table 3). Mill residues did not include blocks, for no end-trimming was done at sawmills.

Table 3.--Output of usable residues by species and class of material, 1951

Species group	Logging residues		Mill residues	
	Cords	Percent	Cords	Percent
Southern pines	32,450	79.9	48,178	85.7
Yellow-poplar	3,824	9.4	3,915	7.0
Sweetgum	1,585	3.9	1,732	3.1
Other soft-textured hardwoods	519	1.3	528	.9
Oaks	1,862	4.6	1,551	2.8
Other hard-textured hardwoods	355	.9	290	.5
Total	40,595	100.0	56,194	100.0

Judging by the number of sawmills operating in the spring of 1952, the 1952 output of pulpable residues was probably equal to 1951. However, from a procurement standpoint, total quantities are not too meaningful. It is also necessary to know how stable the output is, how much of it is economically accessible, and how much is actually available for purchase at various prices.

Stability of Output

Monthly statistics of small-mill lumber production in South Carolina, covering the period 1942-1946, show little seasonality of output. The 1951 behavior of the Delta sawmills followed much the same pattern. Residues produced during the first quarter-year, the period of maximum idleness, were only 9 percent below those for the third quarter, the period of peak activity (table 4). The fluctuations that did occur were largely the result of weather conditions. Yet, in general, lumbering is less affected than pulpwood production

by rain, and the reason is not hard to find. Logging is by mule and tractor-drawn log cart (or by truck along a few well-placed woods roads); pulpwood is bunched by hand to trucks that must maneuver throughout the cutting area.

Table 4.--Output of usable residues by quarters and class of material, 1951

Quarter of year	Logging residues	Mill residues
	Cords	Cords
First	9,721	13,456
Second	10,107	13,990
Third	10,721	14,841
Fourth	10,046	13,907
Total	40,595	56,194

Although seasonal fluctuations are not large, lumber production is subject to considerable variation over a period of years. There are many idle and part-time mills which are not fully employed even in boom times. This excess capacity, plus the presence of a multitude of small hand-to-mouth producers, makes for a highly unstable situation, where a moderate shift in the demand for lumber produces an exaggerated response in terms of production. For instance, a slack demand for lumber during the spring and summer of 1949 idled large numbers of small sawmills and temporarily reduced production some 30 percent or more. By year's end, production had returned to normal. To a pulpmill using lumber residues, periodic ups and downs like this might well pose a more serious problem of supply than the seasonal effects. As protection against slumps, a pulp company could adopt the following measures:

1. Maintain a proper balance between the procurement organizations furnishing lumber residues and round wood. Residue purchases can then be expanded to compensate for seasonal and other temporary shortages of round wood, while round-wood purchases can be similarly expanded at times of recession in the lumber industry.

2. Favor the better-financed and more efficient sawmills by preferential contracts. This would probably be a wise policy in any case.

3. Maintain contacts with sawmills and lumber concentration yards outside the usual group or procurement area, so they can be drawn upon when the need arises.

Accessibility

The question of economic accessibility can, of course, have no one answer. Residues which could be profitably salvaged by one operator or one method might be unprofitable for another. Nevertheless, certain factors of location and concentration of material largely determine the point of marginality for each man or method. One of these factors is distance to a rail loading point.

There are no pulpmills within feasible trucking distance of the Delta area, so shipment must be by rail. Two methods of assembling and loading seem worthy of consideration. The first is to truck all material to a central concentration point, such as Delta, for possible processing and shipment. The second is to load at the nearest siding. Which is the more practicable will depend in part on where the residues are located.

To provide information on this point, all the timber tracts where logging or sawmilling activities were in progress as of May 1, 1952, were spotted on county highway maps (fig. 3), and the volume of residue to be produced at each site was tabulated. Table 5 shows for these May 1952 logging chances and mill sets the volume of residue by hauling distance to Delta, table 6 the volume by hauling distance to the nearest siding for each of the five railroads serving the area.

Table 5.--Sites and usable residues by class of material and trucking distance to Delta, May 1, 1952

LOGGING RESIDUES

Zone	Sites		Volumes	
Miles	Number	Percent	Cords	Percent
0- 5	0	0	0	0
6-10	4	3.9	858	8.5
11-15	7	6.7	1,261	12.4
16-20	10	9.6	470	4.6
21-25	13	12.5	1,207	11.9
26-30	17	16.3	1,756	17.3
31-35	23	22.1	1,570	15.5
Beyond 35	30	28.9	3,028	29.8
All zones	104	100.0	10,150	100.0

SAWMILL RESIDUES

0- 5	0	0	0	0
6-10	3	3.1	1,289	10.3
11-15	6	6.1	1,413	11.3
16-20	10	10.2	598	4.8
21-25	12	12.3	1,474	11.8
26-30	16	16.3	2,277	18.2
31-35	22	22.4	2,068	16.6
Beyond 35	29	29.6	3,370	27.0
All zones	98	100.0	12,489	100.0

Table 6.--Sites and usable residues by railroad, trucking distance to nearest siding, and class of material, May 1, 1952

CAROLINA AND NORTHWESTERN RAILWAY

Zone	Logging residues				Mill residues			
	Sites		Volumes		Sites		Volumes	
Miles	Number	Percent	Cords	Percent	Number	Percent	Cords	Percent
0- 5	3	2.9	128	1.3	3	3.1	173	1.4
6-10	8	7.7	672	6.6	8	8.2	822	6.6
11-15	3	2.9	189	1.9	3	3.1	235	1.9
16-20	2	1.9	249	2.4	2	2.0	318	2.5
21-25	3	2.9	265	2.6	3	3.1	335	2.7
26-30	9	8.7	1,051	10.4	7	7.1	1,449	11.6
Beyond 30	76	73.0	7,596	74.8	72	7.4	9,157	73.3
All zones	104	100.0	10,150	100.0	98	100.0	12,489	100.0

CHARLESTON AND WESTERN CAROLINA RAILWAY

0- 5	6	5.8	965	9.5	5	5.1	1,194	9.6
6-10	10	9.6	597	5.9	9	9.2	710	5.7
11-15	10	9.6	1,605	15.8	10	10.2	2,158	17.3
16-20	13	12.5	1,367	13.5	11	11.2	1,266	10.1
21-25	4	3.8	1,017	10.0	4	4.1	1,241	9.9
26-30	3	2.9	206	2.0	3	3.1	287	2.3
Beyond 30	58	55.8	4,393	43.3	56	57.1	5,633	45.1
All zones	104	100.0	10,150	100.0	98	100.0	12,489	100.0

COLUMBIA NEWBERRY AND LAURENS RAILWAY

0- 5	18	17.3	771	7.6	19	19.4	1,017	8.2
6-10	21	20.2	3,023	29.8	20	20.4	3,811	30.5
11-15	9	8.7	1,212	11.9	9	9.2	1,613	12.9
16-20	6	5.7	861	8.5	4	4.1	1,286	10.3
21-25	9	8.7	1,278	12.6	7	7.1	1,214	9.7
26-30	9	8.7	423	4.2	8	8.2	486	3.9
Beyond 30	32	30.7	2,582	25.4	31	31.6	3,062	24.5
All zones	104	100.0	10,150	100.0	98	100.0	12,489	100.0

SEABOARD AIR LINE RAILROAD

0- 5	8	7.7	550	5.4	8	8.2	665	5.3
6-10	24	23.1	3,503	34.5	22	22.4	4,534	36.3
11-15	8	7.7	1,182	11.6	8	8.2	1,531	12.3
16-20	18	17.3	1,481	14.6	17	17.3	1,894	15.2
21-25	15	14.4	931	9.2	13	13.3	1,146	9.2
26-30	13	12.5	1,309	12.9	12	12.2	1,280	10.2
Beyond 30	18	17.3	1,194	11.8	18	18.4	1,439	11.5
All zones	104	100.0	10,150	100.0	98	100.0	12,489	100.0

SOUTHERN RAILWAY SYSTEM

0- 5	31	29.8	2,051	20.2	30	30.6	2,585	20.7
6-10	37	35.6	2,557	25.2	35	35.7	3,177	25.4
11-15	15	14.4	2,003	19.7	14	14.3	2,358	18.9
16-20	6	5.7	1,308	12.9	6	6.1	1,575	12.6
21-25	7	6.7	1,255	12.4	5	5.1	1,514	12.1
26-30	4	3.9	190	1.9	4	4.1	225	1.8
Beyond 30	4	3.9	786	7.7	4	4.1	1,055	8.5
All zones	104	100.0	10,150	100.0	98	100.0	12,489	100.0

Apparently, Delta is not too convenient a concentration point for lumber residues. Only about 26 percent of the residues were within 20 miles, and over 28 percent were beyond 35 miles. There were two reasons for this. First, there were no sawmills operating in the immediate vicinity of Delta and, second, there were no direct connections by paved highways between Delta and certain areas to the east and west. Other places (Newberry, for example) are more favorably situated.

As might be expected, trucking distances to the nearest rail sidings were much less than to any single concentration point. For instance, 78 percent of the residues were within 20 miles of sidings on the Southern Railway, the one with the greatest track mileage in the Delta area. Sixty-eight percent were within 20 miles of the Seaboard Air Line Railway. This is a decided advantage for decentralized loading points, but other considerations (such as the desire to handle residues mechanically) may carry equal or greater weight in the selection of concentrating methods.

A second factor related to location is the volume of usable residues per site. The logs sawed at custom sawmills, for example, are cut almost entirely from small groups of trees, or even single trees, widely scattered over many farms. The amount of logging residue at any one spot is not sufficient to justify salvage, even by the landowner himself. There are also several stationary commercial mills that employ mobile logging crews and purchase timber in patches an acre or less in size. All together, 35 mills were found whose logging residues were considered inaccessible for this reason. For 1951, these residues by species were estimated as follows:

	Cords
Pines	1,173
Soft hardwoods	299
Hard hardwoods	191
	1,663

All the residues on the May 1952 timber tracts and portable mill sets were considered at least potentially accessible. Of course, there were also conveniently-located mill residues at permanent or stationary mills, even though some of the logging residues were scattered. How much of the May 1952 residues was actually salvable would depend in part on the volumes per site. Table 7 shows the distribution of sites and residues by volume classes.

Perhaps the most obvious of the factors relating to location is the actual physical accessibility of a site--its distance from the nearest road and the nearest all-weather road, the topography and type of soil, the presence or absence of obstacles such as rocks, swamps, high stumps, or a dense growth of young timber. The Delta area is unusually fortunate in this respect. It is rather densely populated for a rural area, and individual land holdings are relatively small. As a

consequence, few timber tracts are more than a quarter-mile from one or another of the closely spaced roads. A high proportion of these roads are paved, and nearly all have received some surface treatment. The topography is rolling to rough and gullied, but not sufficiently to impede logging in most sections. Rocks, swamps, and similar obstacles are rare. Most troublesome are the soils, which are chiefly clays. They are definitely a limiting factor when wet but do not affect one portion of the Delta area much more than another.

Table 7.--Sites and usable residues by class of material and volume per site, May 1, 1952

Residue per site class	Sites		Volumes	
Cords	Number	Percent	Cords	Percent
LOGGING RESIDUES				
Less than 25	10	9.6	137	1.3
25- 49	27	26.0	986	9.7
50- 74	22	21.2	1,297	12.8
75- 99	18	17.3	1,529	15.1
100-199	20	19.2	2,629	25.9
200-299	3	2.9	726	7.2
300 or more	4	3.8	2,846	28.0
All classes	104	100.0	10,150	100.0
SAWMILL RESIDUES				
Less than 25	14	14.3	210	1.7
25- 49	19	19.4	669	5.3
50- 74	16	16.3	995	8.0
75- 99	15	15.3	1,290	10.3
100-199	21	21.4	3,010	24.1
200-299	5	5.1	1,221	9.8
300 or more	8	8.2	5,094	40.8
All classes	98	100.0	12,489	100.0

It is on the accessibility of tops and other scattered residues that the factors of location exert the greatest effect. Slabs and edgings, concentrated as they are at the mill sets, require no bunching or woods travel. Furthermore, one of the main considerations in placing a mill is to select a site from which heavy loads of lumber can be easily trucked. A site so selected is equally favorable for the removal of mill residues. Thus, location of mill sets is seldom critical except where the hauling distance is excessive.

Even in the case of logging residues, location is seldom the main determinant of economic accessibility. Whether the topwood on a cutover tract is or is not operable is more likely to depend on the concentration. Two factors are involved--volume of topwood per acre and volume per top. Both affect the time required for every salvage operation from limbing to loading. However, in the Delta area, sawtimber tends to uniformity of size and form. Consequently, the tops are also uniform. Pine tops, for instance, very seldom contain more than two pulpwood bolts, and the one-bolt tops are usually the larger in diameter. This leaves volume per acre as the chief measure of operability.

Bunching and loading costs are particularly sensitive to differences in volume per acre. Forty-six truckloadings timed on one pulpwood operation showed the following relationship between man-hour requirements and volume of wood per acre:

Cords per acre	Man-hours per cord
1	1.75
2	1.65
3	1.55
4	1.50
5	1.40
6	1.40

Limbing and bucking times are similarly affected, though to a lesser extent. Table 8 shows the distribution of the May 1952 logging sites and residues by volume per acre.

Table 8.--Timber tracts and usable logging residues by volume per acre, May 1, 1952

Residue per acre class	Tracts		Total residues	
Cords	Number	Percent	Cords	Percent
Less than 0.5	10	9.6	229	2.3
0.5 - 0.9	29	27.9	1,394	13.7
1.0 - 1.4	42	40.4	4,853	47.8
1.5 - 1.9	15	14.4	2,157	21.3
2.0 - 2.4	8	7.7	1,517	14.9
All classes	104	100.0	10,150	100.0

Competing Uses

So much for the physical factors of location and concentration. There is also the matter of the already existing uses for these materials. To investigate this aspect, 55 logging chances and 55 sawmill sites were selected at random from those originally visited in May 1952. These were reexamined and the landowners interviewed 8 months later in January 1953. By that time, insect damage and decay were so advanced as to preclude salvage of remaining residues for anything other than fuel. Discussions with owners were depended on to indicate how much was yet to be used for this purpose. Tables 9 and 10 show what became of the residues.

Table 9.--Disposition of usable logging residues on 55 sample logging chances, 1952[1/]

Disposition	Residues	
	Cords	Percent
Sold as pulpwood stumpage	377	7.7
Sold as cut pulpwood	261	5.3
Sold as car stakes	12	0.3
Used as home fuel	50	1.0
Unused	4,202	85.7
Total	4,902	100.0

1/ Sawmill operators sold logging residues from 2 of the 55 tracts; all other sales were by landowners.

Table 10.--Disposition of usable mill residues at 55 sample sawmill sites, 1952

Disposition	Residues	
	Cords	Percent
By the sawmill operators:		
Sold as fuel	468	8.4
Used as home fuel	137	2.4
Given away	146	2.6
By the landowners:		
Sold as fuel	1,051	18.8
Used as home fuel	641	11.5
Given away	132	2.4
Unused	3,012	53.9
Total	5,587	100.0

Mill residues are better utilized than logging residues. Firewood is the chief product, and slabs are favored because they are conveniently piled at accessible locations and can be readied for use with a buzz saw. Tops and broken trees, on the other hand, are scattered and have to be worked up by hand in the woods. Since there is more than enough slabwood to supply all needs, practically no tops are cut up for fuel. Indeed, only 14 percent of those on the sample tracts were salvaged for any purpose, and nearly all of them for pulpwood. By contrast, 46 percent of the slabs and edgings were used.

Sixty percent of the pulpwood from tops was cut by commercial producers, the remainder by landowners. A small number of car stakes were also cut and sold. Only a few of these operations resulted in complete clean-up.

The salvage of sawmill residues is similarly spotty. Stationary mills near well-settled areas are ordinarily able to sell all their slabs and edgings. A number have installed cordwood saws and deliver slabwood in stove lengths at $13 to $15 a cord. At the other extreme are portable sawmills operating in thinly-populated areas. However, about 60 percent of the operators sell at least a portion of their slabs and edging strips, and the mill crews take a small additional quantity for home use.

The greatest volume is utilized after the sawmill moves on. Landowners sold slabs from half of the mill sets examined, supplied themselves and their tenants, and gave wood to their neighbors. All together, they salvaged nearly two and a half times as much material as the sawmill operators. Nevertheless, 54 percent of the mill residues were left unused. Of course, before this surplus rots, much of it will be taken and used by outsiders, but without financial benefit to the owners.

In appraising the possibilities for salvaging added volumes of sawmill and sawmill logging residues for pulping, it may be helpful to note the prices at which these materials have been selling. The values presented in table 11 are based on the prices that prevailed from the late spring to early winter of 1952. They are for the residues "as is" before assembling or preparation of any kind. Volumes unused or given away are considered to be valueless; volumes used as home fuel have been assigned values based on the prices reported for actual fuelwood sales. The volumes corresponding to the given dollar values were obtained by applying the distribution of the sample tract and mill set volumes to the total 1951 outputs of residues.

The resulting schedules show the approximate market valuation of the current annual residue output. Since the volumes are cumulative, each represents the quantity available at the stated price or less. Of course, any substantial increase in demand, as by launching a large purchase program, would tend to raise prices all along the

line. It should also be noted that there is an error attached to including all unused residues as a lump-quantity of zero value. Actually, if potential buyers appeared, they would undoubtedly find that most owners had minimum prices below which they would refuse to sell and that these prices varied by individuals.

Table 11.--Usable residues sold annually by price and class of material[1/]

Price per cord[2/]	Volume available			
	Logging residues		Sawmill residues	
Dollars	Cords	Percent	Cords	Percent
0	34,900	86	36,000	64
.25	35,000	86	38,800	69
.50	35,100	86	41,000	73
.75	35,200	87	43,300	77
1.00	35,300	87	45,500	81
1.50	36,900	91	48,900	87
2.00	38,600	95	52,300	93
2.50	40,600	100	55,100	98
2.75	--	--	56,200	100

1/ Based on supply and demand situation prevailing in 1952.

2/ For residues "as is" before assembling or preparation of any kind.

TOPWOOD SALVAGE PROBLEMS AND METHODS

Sawtimber tops are now being sold to pulpwood producers in the Delta area at "stumpage" prices ranging from 75 cents to $2.50 per cord. However, there is only one producer who specializes in topwood, and tops alone are seldom salable.

In most cases where pulpwood cutting follows sawlogging, the main attraction is the residual stand. Tops and broken trees are worked up as the standing trees are removed, but more often than not the smaller or more scattered tops are left. Thus, although some logging residues are utilized on nearly a third of the cutover tracts, less than 15 percent of the volume is taken.

The deterrents to more complete salvage are partly sociological and partly economic. In the first place, working tops into pulpwood is harder labor than pulpwood production from standing trees. Bucking is now done largely with power saws, but limbing is still a hand operation, and tops require almost twice as much limbing time per cord as

whole trees. If the tops are old and seasoned, the task is hard on both the axe and the man. Also objectionable to woods workers is the fact that limbing forces a man to work apart from his fellows in lonely silence. It would appear that pulpwood producers who avoid salvage cuttings are sometimes more influenced by factors such as these than by any real knowledge of the costs involved.

As a clue to the importance of cost in limiting topwood utilization, time studies were made on five pulpwood operations where both tops and standing trees were being cut. On these operations, the pulpwood bolts produced from trees and those from tops were of the same average diameter, and the timing was so arranged as to minimize differences due to the relative volumes of trees and tops per acre. Under these conditions of equal-size bolts and equal volume per acre, there was no consistent difference in the cost of wood from trees and tops. For three of the operators, topwood was cheaper; for the other two, tree-wood. Apparently, the extra time required to limb tops is approximately balanced by the time required to fell trees. The implication is that when bunching and loading costs, which are rather sensitive to volume per acre, are taken into account, tops and residual trees together will usually make for a more profitable operation than the residual trees alone. The chief exception is the tract on which the tops are dried hard or will yield only one stick of pulpwood each.

Where only tops are available for cutting, the consensus among pulpwood producers is that the operation cannot be made to pay. The one producer in the Delta area who operated tops exclusively was believed to be making money, but it may well be he could have done better by purchasing regular pulpwood stumpage. In any event, the use of topwood cannot expand very rapidly as long as the producers feel there is more profit in cutting standing timber. Presumably, the only thing that could change their minds is a disproportionate rise in the price of pulpwood stumpage.

It also seems unlikely that farmers and other landowners will produce any worthwhile volume of pulpwood from the logging residues on their lands. For years, foresters have tried to interest farmers in woods work and, when the introduction of woodyards made truckload sales of pulpwood easy, it was thought that farmers might become substantial producers. This expectation has not been realized.

In the Delta area, where scarcely a woodland is more than 15 miles from a woodyard, the owners of only 3 out of 55 cutover tracts attempted to produce pulpwood from their logging residues. Of 44 who gave reasons for not doing so, only 15 thought it would have been uneconomic. Lack of labor or equipment was the main obstacle.

The only other potential producer of pulpwood from tops is the sawmill operator. Certainly, if tops are operable at all, the sawlog crew is in a favorable position to work them up. Other things being equal, it should be cheaper to remove them simultaneously with the

logs than later as a separate operation. There is also an opportunity to reduce costs through the use of logging machinery which the average pulpwood producer could not justify. This might involve tree-length logging on the more level sites or the handling of entire tops as though they were logs, bunching them with the logging mules or even transporting them from the woods via tractor and log cart before bucking. However, right now, lumbermen are not inclined to experiment with pulpwood production.

At present, the return per unit of labor from lumber is enough higher than that from pulpwood to discourage sawmill operators from working up their sawtimber tops. They fear that by so doing they might be hampering their principal activity in favor of one less profiable. This objection does not apply to selling slabs and edgings for pulping; the operators anticipate this can be done as a separate activity which will not affect the regular production routine. When and if lumbermen start selling these mill residues, their outlook toward integrated lumber and pulpwood production may change.

SLABWOOD SALVAGE PROBLEMS AND METHODS

As previously noted, large sawmills are scarce in this region. Three-quarters of our lumber is produced at mills little or no larger than those around Delta, and the proportion increases every year. Therefore, if any substantial volume of residues is to be salvaged for pulping, it must be done under conditions essentially similar to those prevailing in the Delta area.

This obviously introduces a number of problems that would not be encountered were it possible to deal only with a few large lumber plants. Most troublesome are the problems of (1) negotiating with so large a number of potential sellers, (2) overcoming the small lumberman's aversion to activities not directly contributing to lumber production, (3) transporting the residues economically from source to pulpmill, (4) deciding how and where the debarking can be done most efficiently, and (5) deciding how and where the chipping can be done most efficiently.

Ownership of Residues and Number of Sellers

The first point a prospective purchaser of lumber residues must consider is the number of sellers with whom he will have to deal. Some 450 timber tracts are logged annually in the Delta area, largely by portable sawmills. Presumably, an almost equal number of landowners are involved, and few of them have timber to sell any two years in a row. Thus, to buy residues from the landowners would require a prohibitive number of contacts with no opportunity to establish lasting business relations. It would be much simpler to deal with the sawmill

operators, 20 of whom produce about 40 percent of the usable residues (table 12). Or, perhaps, arrangements could be made through the 12 concentration yards that handle practically all the lumber from the sawmills.

Table 12.--Sawmills and usable sawmill residues by 1951 residue output

Residue output class	Mills		Residues	
Cords	Number	Percent	Cords	Percent
Less than 100	60	40.8	2,613	4.6
100- 199	10	6.8	1,633	2.9
200- 299	11	7.5	2,874	5.1
300- 399	10	6.8	3,684	6.6
400- 499	14	9.5	7,119	12.8
500- 599	7	4.8	4,067	7.2
600- 699	7	4.8	4,932	8.8
700- 799	8	5.4	6,761	12.0
800- 899	6	4.1	5,753	10.2
900- 999	6	4.1	6,394	11.4
1,000-1,099	4	2.7	4,522	8.0
1,100-1,199	1	0.7	1,324	2.4
1,200 or more	3	2.0	4,518	8.0
All classes	147	100.0	56,194	100.0

If negotiations are to be restricted primarily to mill and yard operators, prevailing methods of purchasing sawtimber may have to be altered. Present lease agreements take two forms, according to whether the purchase price is to be paid as a lump or in installments as the timber is cut. When sawtimber is bought "by the boundary" for a lump sum, the lumberman frequently receives title to every part of the trees he cuts, and almost invariably to the slabs, strips, and sawdust. Upon expiration of the lease, residues revert to the landowner. However, only a third of the timber transactions in the Delta area are by the boundary, and the proportion is steadily decreasing.

The other two-thirds of the sales are by the thousand board feet lumber tally. Under the terms of a lumber-tally agreement, the timber is paid for as it is sawed, and the purchaser ordinarily receives title only to the actual lumber he produces. All residues are the property of the landowner.

Although lumber-tally transactions have certain disadvantages, they are generally considered more equitable to both parties than sales by the boundary. Other advantages claimed for lumber-tally payment are (1) it keeps sale cost down by obviating the need for cruises by either buyer or seller; (2) the lumber delivery tickets or invoices are a convenient record of the volumes for which payment is owing, and

the books of lumber buyers can be consulted to settle disputes; (3) payment is by installments, so the buyer is not forced to raise a large cash sum in advance of cutting; and (4) since a lumber-tally price is a unit price, sales in a locality tend to establish a recognized market value for timber and thereby contribute to orderly selling.

These advantages have made lumber tally the favored basis of sale. However, since this type of timber lease does not automatically transfer title to residues, it may be necessary to cover them by separate agreement stipulating price and method of measurement.

The Lumberman's Attitude

The Delta sawmills, like most sawmills in this region, are producers of millrun lumber. Their output is not priced according to grade. Depending on the demand, certain sizes of lumber may bring more than others but, aside from this, success is measured entirely in terms of gross production per man-hour and per machine-hour. Speed and efficiency are practically synonymous. For this reason, lumbermen shy away from secondary activities likely to distract them from or interfere with their main purpose of maximum production.

If slabs can be sold in the pile, or if sawmill crews need only stack them in loading racks for hauling to nearby markets, large volumes will become available at a comparatively low price. If the sale of slabs involves hunting for a buyer, sorting or other special preparation, ordering railroad cars, or operating under a short-term quota, the costs will rise. In addition, supervisory attention is diverted from the real business at hand, which is producing lumber. As a result, the supply price of the residues may increase out of all proportion to the extra preparations involved.

An illustration of this principle is the operators' present attitude toward the sale of slabs for firewood. Large quantities of whole slabs are currently being delivered distances up to 10 miles at prices averaging $4.25 per cord. Slabs cut into stove lengths bring $14.50 per cord, but this higher price attracts only a handful of operators. Most apparently feel that the added income does not justify the extra equipment, labor, and sales effort required.

To overcome this resistance to adding other enterprises to that of producing lumber, either the selling of slabs for pulping must be made easy, or a relatively high price must be offered. Only in these ways can any large part of the potential slab supply be tapped.

Transportation

The third main problem of slabwood salvage is that of transportation. Slabs, as they come from the saw, contain a great deal of bark. In the case of pine slabs, for example, the bark is nearly 25

percent of the volume. This bark is as heavy as the wood and, at present, is useful only as boiler fuel. Therefore, it is not economical to transport it any great distance.

Also troublesome are the irregular shapes and random lengths of slabs, which make them difficult to load solidly on open-bunk or flat-bed trucks, the only types most sawmills own. Box or rack trucks, even if available, would not be too practical, since they would complicate the unloading. The truck haul from sawmill to first destination might be made easier by means of specially designed pallets or steel strapping. However, if these package-loads were to be hauled on sawmill trucks, they would require some sort of self-loading racks, since devices capable of lifting so much weight are seldom to be found at small sawmills.

For long hauls or rail shipment, even these methods would not be too effective in reducing cost. For one thing, the "pay load" would be seriously limited by the high proportion of bark. Therefore, the bark should be eliminated as near the source as possible, i.e., at the sawmill or a rail loading point. At the same time, it might be possible to chip the slabs.

Chips have the advantage of being easily loaded and unloaded by means of conveyors, impellers, or blowers at about half the cost of standard pulpwood bolts. The costs of loading and unloading solid slabwood would presumably exceed those of round pulpwood, at least by hand methods.

After chipping, a 128-cubic-foot cord of wood occupies 200 cubic feet of space. Thus, a standard 40-foot box car loaded 8 feet deep with pine chips would contain the equivalent of 14.5 cords of wood, and the chips would be likely to weigh between 55,000 and 60,000 pounds. This compares favorably with the average loading of round pulpwood in box cars. In the West, chips are transported distances up to 70 miles by heavy truck and 200 by rail.

Bark Removal

At present, there is no whole-log barker designed for small-mill use. One may soon be placed on sale at about $5000, but even this investment would be hard to justify at a mill sawing less than 3 million board feet a year. In fact, the barker and its power unit would approach the average operator's total investment in mill, trucks, and logging equipment. In the case of portable sawmills, the barker would also add another piece of heavy equipment to be moved from place to place. Thus, for the immediate future, at least, log barking does not appear to be the complete answer to the problem of bark removal.

Experiments by southern pulp companies have included a number of attempts to debark slabs in the large drums designed for round wood. These tests showed that only the heaviest slabs could be successfully debarked in this manner. Since hand-peeling was clearly too expensive, an effort was made to sort out slabs suitable for drum-barking. This also proved impracticable, because it involved so much handling.

Outside the South, efforts to peel slabs have been more specialized and more successful. In the West, hydraulic slab barkers have been in operation for a number of years. They do a clean job and are said to waste little wood. However, their cost and high power and water requirements prevent their use except where there are great concentrations of slabs, as at a pulpmill. Specially-designed drum barkers are also reportedly in use.

In eastern Canada, slabs are sometimes barked by small cutterhead peelers known as "buzz barkers." With a 2-man crew, these barkers can process 5 cords a day.5/ Their principal disadvantage is that the average yield of chips is only 0.4 units (of 200 cubic feet) per thousand board feet compared to 0.6 units when whole-log barkers are used. So great a loss (one-third) might well be prohibitive if the slabs were purchased and transported some distance before peeling. On the other hand, buzz barkers are inexpensive to purchase, require little power, and have sufficient capacity to handle the full output of a sawmill cutting 10 to 12 thousand board feet a day.

More promising, in some respects, are the possibilities of removing the bark after chipping rather than before. During the peeling season, the jar of the chipper knives alone is sufficient to separate bark and wood. At other seasons, further treatment is needed. Eberhardt6/ has described the "shaker aspiration" method of removing bark from chips. The equipment for the process consists of a "drubber," screens, and an aspiration hood. The drubber sizes the chips and knocks the bark loose from the wood. Leaving the drubber, the chips pass to screens that remove those that are over-size for further reduction in the drubber, and thence to smaller-mesh screens that remove the fines, which are principally bark. Bark still remaining with the acceptable chips is separated under the aspiration hood. In this way, all but 4 to 7 percent of pine bark is removed. The accompanying loss of wood is only about 10 percent, and output is 4 tons of chips per hour. Shaker aspiration equipment is now ready for commercial installations in this region.

5/ Jenkins, J. H. Wood waste utilization in Canada. Canada Dept. Res. & Dev., Forestry Branch Bul. 103, 1952.

6/ Eberhardt, L. (Bauer Bros. Co., Springfield, O.). Removal of bark from chips and wood pulp. Paper Trade Jour. Vol. 135, No. 25, Dec. 19, 1952

Another alternative to peeling logs or slabs is to chemically debark the standing trees. Under this method, the trees are girdled and a solution of sodium arsenite applied to the girdles. Trees so treated during the late spring die within a few days and are largely bark-free by fall. However, the method has three drawbacks when applied to sawtimber in this region. The first is that few lumbermen buy timber very far in advance. Second, any cautious landowner would insist on payment in full before poisoning began, thus forcing the purchaser to tie up his money for several months. Third, and most important, is the possible depreciation in the value of the dead trees through insect damage and stain.

So much for the mechanics of debarking. Apparently, devices already available make it feasible to remove bark at the source, at a pulpmill, or at an intermediate concentration point. Other equipment and methods will undoubtedly appear when there is a demand for them. Thus, it seems safe to assume that factors other than the limitations of the equipment will determine where the debarking can best be done. Such considerations as a desire to keep portable sawmill equipment weights low, the need to eliminate bark-weight before rail shipment, or the possible economies of large-scale, semiautomatic operation will more than likely dictate not only where the debarking is to be done but the type of machinery required.

Chipping

Closely akin to the problem of debarking is that of chipping. The gravity-feed chipper is the one commonly used to chip round wood at pulpmills. Its advantages are speed and easy adaptability to sticks with a broad range of diameters. However, gravity-feed chippers have not been too satisfactory in tests with slabs, the light weight and irregular shape of which cause them to jump in the hopper and produce chips that are not uniform. Short slabs also contribute to the proportion of miscut chips.

Fortunately, there is a solution for this problem. Manufacturers say that force-feed chippers can produce uniform chips from odd-shaped pieces of wood only one foot long. Furthermore, these chippers can be made small enough and light enough to be easily portable. Of course, regardless of the machine used, the best chips are obtained from long material. Thus, crosscutting slabs into standard lengths would reduce the yield of uniform chips.

None of the Delta sawmills has sufficient production to keep a chipper running. Therefore, to handle slabs currently there would have to be a central chipper installation to which whole slabs could be brought from a number of mills.

Greater flexibility would be possible with small portable chippers operated in conjunction with a separation system such as the "shaker aspirator," capable of separating chips into their bark and

wood components. One or more "shaker aspirators" would be installed at a concentration point on a railroad. As soon as a sawmill moved from a set, a chipper would move in to salvage the slab pile. Chip delivery could be by semi-trailers.

Since it would presumably cost more to operate several small chippers than one large one, the most effective use of portable chippers might be to supplement a large central installation. The latter would supply most of the ordinary day-to-day chip requirements, while the former provided a means of varying chip output at will. In this way, seasonal fluctuations in deliveries of either pulpwood or slabs could be compensated for.

A Suggested Procedure

From experience to date, it seems evident that rough slabs from small sawmills cannot be directly substituted for round pulpwood. Certainly, they cannot be debarked by usual round-wood methods, and they probably cannot be chipped satisfactorily in existing pulpmill chippers. They also pose a somewhat different transportation problem. Consequently, whether pulp companies are able to utilize sawmill residues profitably will depend, in part, on their willingness to invest in specialized machinery and other new facilities. It will also depend on organizing a procurement system capable of purchasing and assembling slabs from a great number of scattered sawmill sets at minimum cost. Finally, the entire program should be designed to make the selling of slabwood easy for potential suppliers.

If these are the important requirements for success in salvaging sawmill residues, the most promising single solution to the whole problem would appear to be the establishment of conveniently located concentration yards equipped with debarking, chipping, and chip-loading machinery. Rough slabs could reach these yards by short haul on ordinary log or lumber trucks, the chipping operation would be susceptible to strict quality control, and the bark and fines would be eliminated prior to rail shipment. Once at the pulpmill, the chips could be introduced directly into the chip-conveyor system with a minimum of equipment or handling.

Contracts with 20 to 30 of the larger lumber producers should result in yard deliveries of up to 100 cords of slabwood daily in the Delta area. Additional quantities might be obtained as needed by spot-purchase of entire slab piles. An alternative procurement plan is to have a buyer on duty six days a week at each yard prepared to buy, without need of prior agreement, every sound slab delivered and to pay an established, advertised price. Thus, a potential seller would know just what he could get for his slabs whenever he is ready to deliver them. Other slabs might be picked up by yard-operated trucks from custom sawmills and landowners unable to do their own hauling.

Concentration yards might be maintained either by the pulp companies or by contractors. It might even be possible to interest already existing lumber concentration yards in concentrating lumber residues as well

Several paper companies now drawing pulpwood from the Delta area are studying the possibility of purchasing sawmill residues. Some one of them will probably launch a salvage program on a trial basis before many months. When that time comes, the concentration yard approach should receive first consideration.

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Progress in Development of Efficient Turpentining Methods

by

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PROGRESS IN DEVELOPMENT OF EFFICIENT TURPENTINING METHODS

By

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INTRODUCTION

Considerable progress has been made during the past 5 years in the development of more efficient turpentining methods for use on slash and longleaf pines (18,19,20,21,22,23,33).[1/] The backbone of this progress rests in the use of bark chipping, with sulfuric acid treatment on a 2-week schedule. Original work on the use of different chipping systems and treatments with many different chemicals was reported in 1944 (28). This initial summary publication contains a comprehensive digest of all the early work and serves as a progress report on the studies completed before then. A 1948 publication (31) covers the next 4 years of progress in studies of many different turpentine systems, and contains practical recommendations for the producer, based on experimental data collected through 1947.

Since 1947 all of these earlier studies have been completed. In addition, other experiments have furnished further information on more efficient turpentining systems. The present paper will cover the results of all experiments conducted since 1947, and draw conclusions based on the consolidated information gained during the past 10 years of concentrated research effort.

PROCEDURES

The same general procedures described in previous reports (28,31) were followed in the experiments reported in this paper. We had found that the most efficient experimental approach to testing a number of different treatments in naval stores studies consisted of first arranging

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1/ Underlined numbers in parenthesis refer to literature cited.

the trees in groups of similar gum-yielding ability on the basis of yields obtained from an average of four calibration streaks. Then the experimental treatments were assigned at random to the trees within each yield group. Usually 10 to 15 trees were assigned each treatment.

Both slash and longleaf pine are economically important in the naval stores industry, and early studies demonstrated a different treatment response for each species, so duplicate experiments were started in most cases. All experiments were conducted in second-growth stands on the Osceola National Forest in northern Florida. Yields for slash pine were averaged for northeastern Florida. Yields from longleaf were somewhat low, since the longleaf sites available were not the best, though characteristic of many in this area.

Every two or three weeks, depending on the chipping frequency, gum yields were obtained by weighing to the nearest gram. These figures were later converted to gum yields in barrels (435 pounds of gum net) per crop of 10,000 faces. In this way both yield trends and total yields were obtained for individual trees and treatment groups.

The same miscellaneous details of experimental techniques used previously (28,31) were also incorporated in the studies reported in this paper. These include: face widths 1/3 circumference unless otherwise stated; tins fastened on with either tapered cut tacks or double-headed nails, in both virgin and elevating operations, according to modern recommendations (9,24,36); streaks chipped 1/2-inch deep and 1/2-inch high (1/2 x 1/2) with a No. 0 hack; bark chipping (BC) with a standard bark hack or bark puller; chemical solutions applied with the latest Evans or Nichols plastic squeeze sprayer.

FACTORS AFFECTING YIELD OF TREATED TREES

Virgin Cupping Methods

Original studies with deep chipping showed that gum yields were less from trees with gutters inserted with a broadaxe than from trees with the gutters tacked in shallow streaks (29). This decrease in yield with deep gutter insertions was attributed to interference with the movement of necessary food and water.

With increasing numbers of acid users who practice bark chipping, the question arose whether this same loss in gum yield with inserted gutters held true for the new method of chipping. In order to answer this question, the study reported in table 1 was started in 1950.

These results with bark chipping and acid treatment substantiate those of the previous work with untreated deep chipping (29). In addition, they strengthen materially our original concept that the depth of gutter insertion should be no deeper than the depth of chipping. This means that with bark chipping the tins must be fastened on the surface of the exposed wood or on smoothed bark to insure maximum yields.

Table 1.--Relative gum yields for two methods of hanging tins in virgin cupping

Type of installation	Gum yields per crop[1]		
	Slash	Longleaf	
	1951	1950	1951
	Bbls.	Bbls.	Bbls.
Broadaxe incision	256.6	147.6	129.2
Nailed on surface	286.9	198.7	175.4
LSD[2] bbls. per crop	42.4	39.5	42.9

1/ Average yield per crop (10,000 faces) for 32 weeks. All trees were bark chipped every 2 weeks and treated with 50-percent sulfuric acid.

2/ Least significant difference between treatments at 5-percent level. Same level used for all tables in this report.

The data of table 1 show that in slash pine a slight, but not significant increase in gum yield was obtained the first year from trees with gutters fastened on the surface of smoothed bark than from trees with gutters inserted with a broadaxe. In longleaf this increase averaged 35 percent for 2 years of work and was significant at the 5-percent level. This indicates the increased profits that may be obtained with a conservative gutter installation technique, since little or no extra cost is involved.

The availability of "spiral" gutters (24) greatly facilitated conservative virgin tin installation work. The exact method to use is described in detail in a previous publication (9). This latter article also cites the multiple advantages offered by the new method of virgin cupping with spiral gutters. These advantages are:

1. Virgin yields are increased over those obtained with the old axe-maul method.
2. Over-all production costs are reduced, as one cup, one set of double-headed nails, and one set of tins can be used for the life of the face.
3. The chipping of a "healing" or "lead" streak with this method is not necessary. Elimination of this job means more profit per barrel of gum for the producer.
4. Finally, a metal-free tree trunk permits the entire tree to be harvested for sawlogs, pulpwood, or poles, thus returning the greatest value for stumpage following turpentining.

Diameter

Several sources of information about the gum-yield level to be expected from trees of different diameter are available (1,37,38). The yields in these publications were based on the old method of weekly deep chipping. There are no published data on the relative yields from trees of different diameter with bark chipping and acid treatment, except for one study on trees 4 to 8 inches in diameter (31). A study was started in 1949 to obtain relative information on yields to be expected from trees of different diameters when turpentined by the old untreated weekly deep-chipping method, and by the modern system of acid treatment of bark chipping on a 2-week schedule. This study presents the first real evidence that the same relationship holds true with bark-chipped and acid-treated trees (table 2). In both species the maximum yield in acid treated trees

Table 2.--Comparative gum yields for trees 9 to 13 inches d.b.h. worked by different methods

(In barrels per crop)

Treatment[1/]		Gum yield				Yield per inch of face width			
		1949	1950	1951	Average	1949	1950	1951	Average
SLASH PINE									
Untr. 1/2 x 1/2 wkly									
D.b.h.	9.0- 9.9	133.3	142.3	129.0	134.9	14.03	14.98	13.58	14.20
	10.0-10.9	174.5	201.6	181.6	185.9	16.62	19.20	17.30	17.70
	11.0-11.9	174.3	182.3	184.4	180.3	15.16	15.85	16.03	15.68
	12.0-12.9	229.3	226.6	215.5	223.8	18.34	18.13	17.24	17.90
	13.0-13.9	270.3	280.4	274.1	274.9	20.02	20.77	20.30	20.36
Acid BC x 5/8 bwkly									
D.b.h.	9.0- 9.9	152.8	132.0	105.8	130.2	16.08	13.89	11.14	13.70
	10.0-10.9	191.8	164.1	144.5	166.8	18.27	15.63	13.76	15.88
	11.0-11.9	220.3	193.4	156.0	189.9	19.16	16.82	13.56	16.51
	12.0-12.9	300.6	270.5	261.5	277.5	24.05	21.64	20.92	22.20
	13.0-13.9	300.6	252.3	243.9	265.6	22.27	18.69	18.07	19.67
LSD bbls per crop		47.4	49.9	51.4					
LONGLEAF PINE									
Untr. 1/2 x 1/2 wkly									
D.b.h.	9.0- 9.9	114.1	111.8	110.7	112.2	12.01	11.77	11.65	11.81
	10.0-10.9	124.8	116.6	110.9	117.4	11.88	11.10	10.56	11.18
	11.0-11.9	168.6	162.9	160.0	163.8	14.66	14.16	13.91	14.25
	12.0-12.9	166.7	167.6	163.0	165.8	13.34	13.41	13.04	13.26
	13.0-13.9	217.0	213.6	196.9	209.2	16.07	15.82	14.58	15.49
Acid BC x 5/8 bwkly									
D.b.h.	9.0- 9.9	178.8	145.1	127.0	150.3	18.82	15.27	13.37	15.82
	10.0-10.9	215.5	166.0	159.8	180.4	20.52	15.81	15.22	17.18
	11.0-11.9	248.5	215.0	203.8	222.4	21.61	18.70	17.72	19.34
	12.0-12.9	313.5	247.0	236.7	265.7	25.08	19.76	18.94	21.26
	13.0-13.9	290.9	249.3	223.5	254.6	21.55	18.47	16.56	18.86
LSD bbls per crop		59.1	53.7	54.7					

1/ Treatment with 50-percent sulfuric acid; d.b.h. is diameter breast high in inches.

was obtained from the 12-inch diameter class with yield from the 13-inch class dropping off slightly. Bokor 2/ reported on a similar situation on Pinus sylvestris in Hungary. He found that, ".....with untreated chipping, yield increased with d.b.h., reaching a maximum at about 13.7 inches and then changing little, while with hydrochloric acid treatment the yield increases rapidly with d.b.h., reaching a maximum at about 17.7 inches, then declining." We do not know whether or not a similar situation exists in our species since there is no information available on the higher diameter classes from which to establish a definite trend. However, upon examination of the basic yield data it appears that the drop in yield of the 13-inch class is the result of sampling error rather than an indication of a leveling-off point. The average yields that may be expected in the vicinity of Lake City, Florida, are shown in figures 1 and 2.

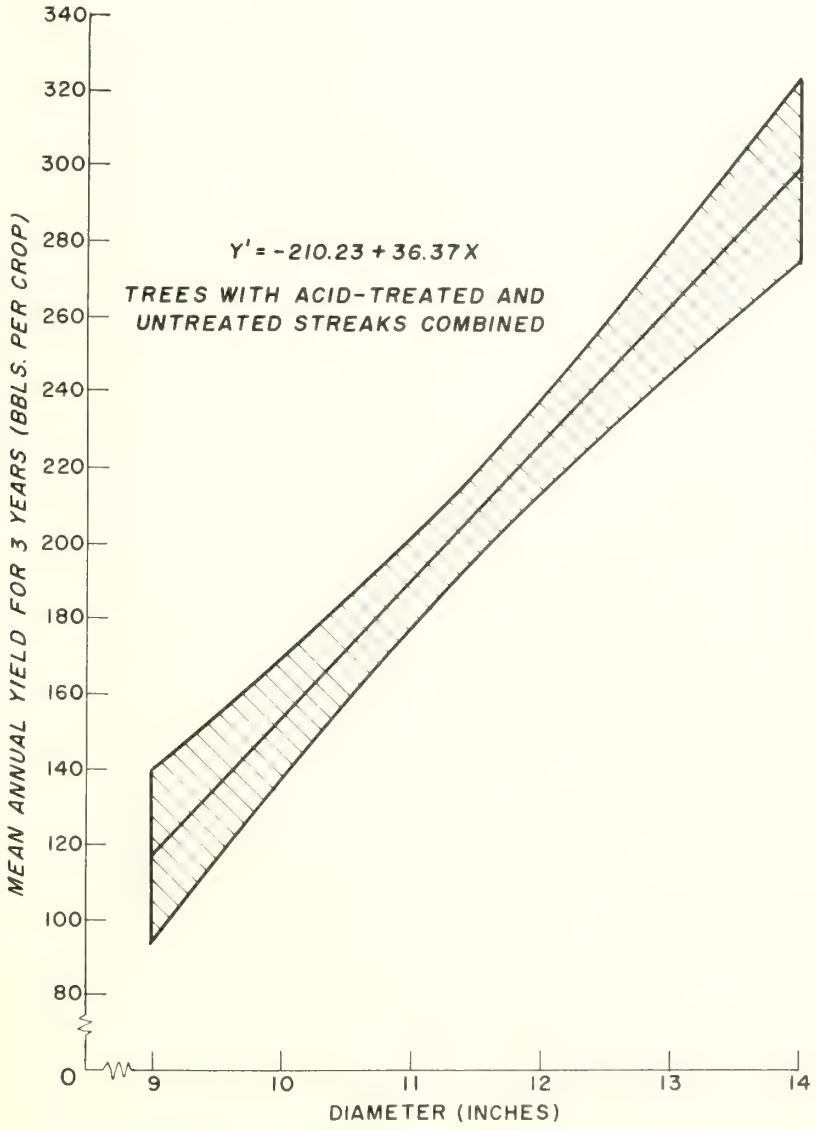


Figure 1.--Relation of gum yield to tree diameter in slash pine. Yields of trees wood chipped every week but not treated, and trees bark-chipped every 2 weeks and treated with acid are combined.

2/ Bokor, R. The intensification of resin production in Hungary. Ann. Fac. Silvat. Univ. Agr. Sopron 1(1): 319-37. 1950.

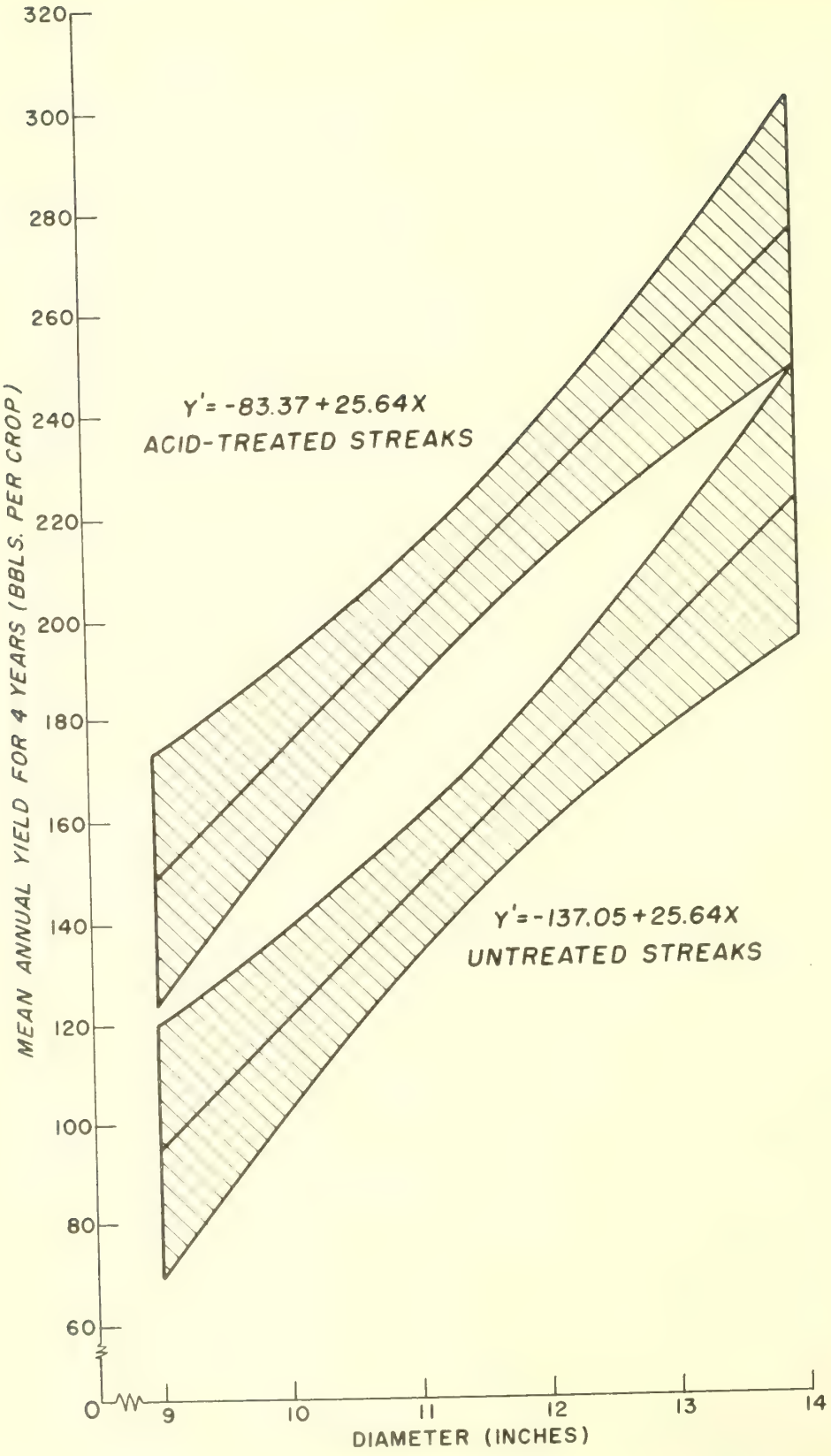


Figure 2.--Relation of gum yield to tree diameter in longleaf pine. Upper line--trees bark chipped every 2 weeks and treated with sulfuric acid. Lower line--trees wood chipped every week and not treated with acid.

Basically one would expect that yields from larger trees would be greater, since face widths of 1/3 circumference were used. Thus larger trees had wider faces, and increased yields might be attributed to these wider faces. However, these data show that tree size has a further influence on yields beyond that of wider faces alone. This is illustrated in the summarized results shown in figure 3. These data also show that the yields per inch of face width are progressively greater as diameters increase.

Many producers ask whether trees smaller than 9 inches in diameter can be worked profitably with modern turpentining methods. A partial answer to this question was given in earlier work (31). At that time, it was felt that some trees in the 8- to 9-inch class could be worked under favorable circumstances. A more intensive study of yields from trees in diameter ranges just below 9 inches gave the results shown in table 3.

The yield level for trees in the 7-inch diameter class is definitely and uniformly low for all treatments in both slash and longleaf. This would be the expected result since the smallest trees were definitely in the intermediate class in a moderately crowded old-field stand. However, yields from 8-inch trees chipped on a biweekly schedule approach the volume needed for a minimum commercial operation. This adds to our previous knowledge and makes it possible to suggest a limited recommendation. These data suggest that 8-inch trees might be worked profitably under specific conditions. We would advocate turpentining of 8-inch trees only if they had good crowns, were not overmature, and only if done prior to intermediate or harvest cuts where removal of these 8-inch trees would benefit the residual stand. Even then, their yield would tend to be marginal, and 8-inch trees should be included mainly for the purpose of making an operable turpentine chance.

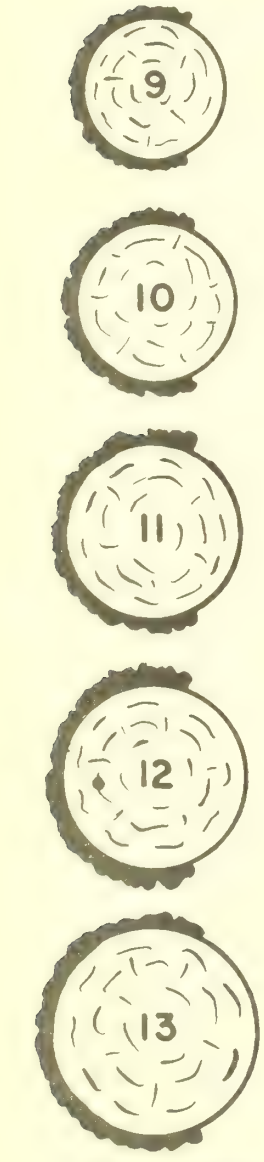
Yield Level

Trees vary considerably in their ability to produce gum. This variation is so great that a few outstanding individuals have been segregated for special work in forest tree improvement (11,12). It is possible that at some future time we will have trees in some of our forests which are mainly high yielders (10). In the meantime we have the common mill-run average to turpentine. Preliminary studies of these trees (31) indicated that different yielding categories occurring in the same uniform stands respond differently to acid treatment. This is further illustrated in the results shown in figure 4.

The relative differences in these results are striking and show a definite trend, as indicated in table 4.

The greatest relative yield increase occurred in the trees which were initially classed as low yielders. The smallest increase due to acid treatment was found in the groups of highest yield level. The answer to the question, "Why do high-yielding trees have a lower response to acid than do low-yielding trees?" is probably closely associated with the total amount of gum produced. We have demonstrated in many studies (28,31) that a certain maximum yield level cannot be sustained over any great period of

DIAMETER IN INCHES (DBH)	SLASH BARRELS OF GUM PER CROP	SLASH BARRELS OF GUM PER INCH OF FACE WIDTH	LONGLEAF BARRELS OF GUM PER CROP	LONGLEAF BARRELS OF GUM PER INCH OF FACE WIDTH
9	130	13.7	150	15.8
10	167	15.9	180	17.2
11	190	16.5	222	19.3
12	278	22.2	266	21.3
13	266	19.7	255	18.9



FACE WIDTH
1/3 CIRCUMFERENCE

(ALL TREES BARK CHIPPED AND TREATED WITH ACID EVERY OTHER WEEK)

Figure 3.--Gum yield from trees of different diameter. Yield per crop nearly doubles from 9 to 13 inches, and yield per inch of face width is also greater in larger trees.

Table 3.--Gum yields obtained from trees in different diameter groups with several methods of working

Treatment[1/]	D.b.h.	Gum yield per crop		Relative gum yields	
		1947	1948	1947	1948
	Inches	Bbls.	Bbls.	Percent	Percent
SLASH PINE					
Weekly (untr.)	9+	212.7	220.7	100	100
Biweekly (acid)	7-8	100.7	106.5	47	48
	8-9	131.1	134.6	62	61
	9+	207.0	230.9	97	105
Triweekly (acid)	7-8	66.0	80.9	31	37
	8-9	83.1	99.1	39	45
	9+	124.7	142.0	59	64
LSD bbls per crop		39.2	44.8		
LONGLEAF PINE					
Weekly (untr.)	9+	141.7	137.1	100	100
Biweekly (acid)	7-8	92.3	80.7	65	59
	8-9	135.3	125.4	95	91
	9+	161.8	150.7	114	110
Triweekly (acid)	7-8	63.3	77.9	45	57
	8-9	92.4	106.8	65	78
	9+	116.0	122.4	82	89
LSD bbls per crop		28.9	36.6		

1/ Weekly trees chipped 1/2 x 1/2; others bark chipped 1/2-inch high. Face widths all 1/3 circumference; sulfuric acid in a concentration of 40 percent for slash and 60 percent for longleaf pine.

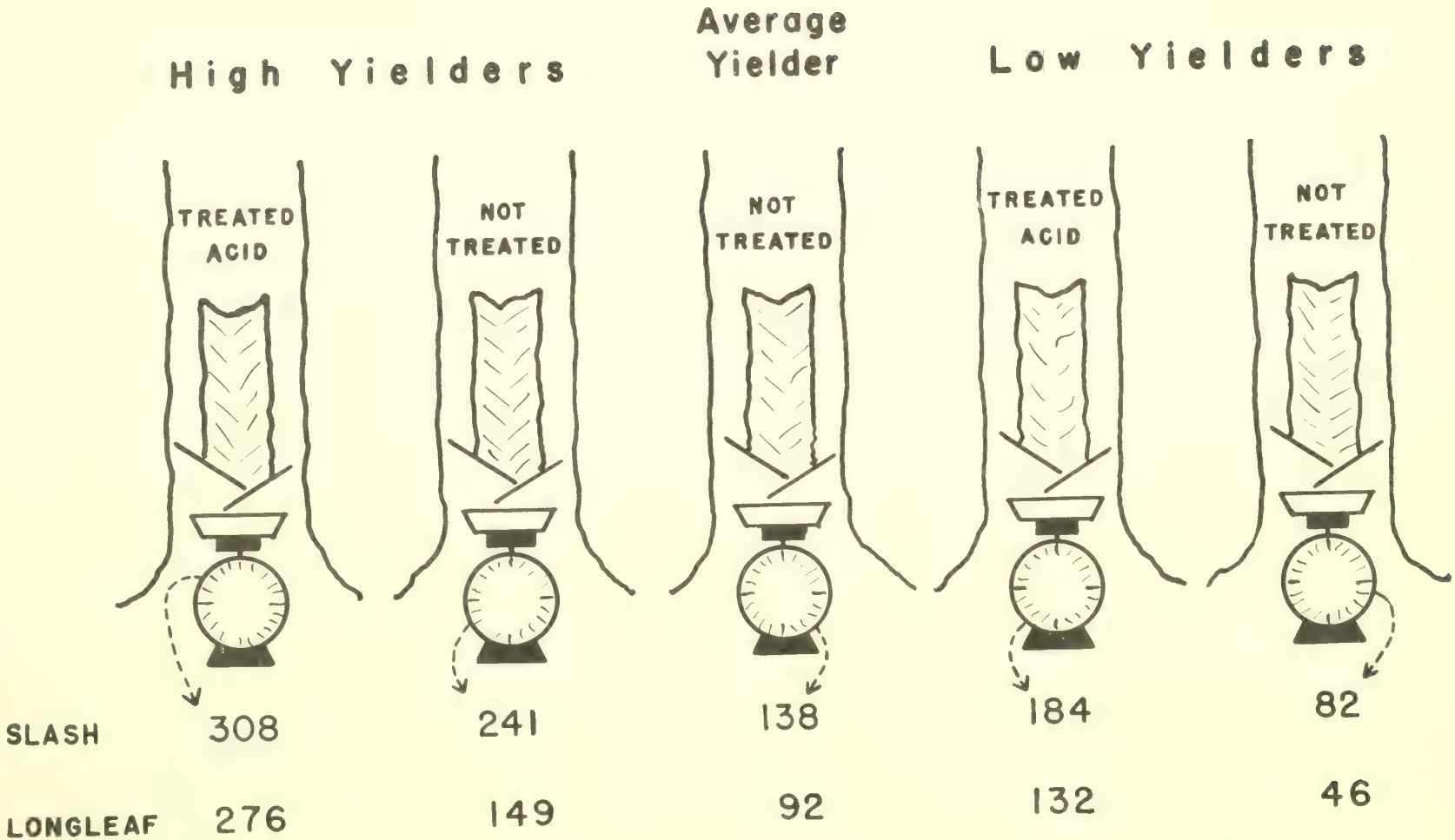


Figure 4.--The effect of acid treatment on yields from high- and low-yielding trees (in barrels per crop).

Table 4.--Relative yield differences for treated and untreated trees of three yield levels

Yield level	Relative difference[1]	
	Slash	Longleaf
	Percent	Percent
High	28	85
Average	86	76
Low	124	187

1/ Percent figures represent the percent yield increase due to acid treatment.

time. High yielders are already producing more gum than average trees. Yield trends show that initially in high yielders the yield boost given by acid lasts for only about 3 months (31). In contrast to this, the yield boost given low yielders by acid is prevalent during most of the season. We can then conclude that temporarily the continuous-yielding ability of high yielders is exceeded, but in low yielders it is not.

Frequency of Chipping and Treatment

One of the most important factors determining the efficiency of turpentining with modern methods is the frequency with which the trees are chipped and treated. In the old days of deep chipping the trees were visited about once a week during the regular season. Sometimes during the hot months of July and August more frequent visits were made to chip the trees (1). There was an abundant supply of labor in those days.

Now the picture is different, with labor hard to get and difficult to keep. But with less labor and the use of modern bark chipping and acid treatment, the turpentine operator can still produce as much gum as before and produce it more efficiently. This involves the use of chipping intervals of 2 weeks. A laborer can handle nearly twice as many trees, and with the increased yield resulting from the use of acid produce as much gum as two men working with old-fashioned methods.

Because of the importance of the frequency of chipping and treatment, considerable work has been reported previously (2,3,4,5,6,7,28,30,31) on this subject. These publications have covered most of the advantages of the several frequencies that may be used, and point out which will be best for any given situation. Also, most of the other work reported in this paper contains information on the relative efficiencies of schedules of 1-, 2-, or 3-week chipping intervals.

Additional work not reported before is summarized in table 5. This study covers 6 years of front-face work, and an additional 2 years of back-face results. Although general yield levels are low, the yields over the entire period of 8 years are good with a 3-week chipping and treatment schedule. This 3-week schedule is particularly good in longleaf, and further emphasizes identical results of infrequent schedules obtained in other longleaf experiments. Slash pine results are not so outstanding, but on the basis of yield per streak, compare favorably with regular weekly deep chipping.

Table 5.--Comparative gum yields for 8 years of work by two different treatment methods

(In barrels per crop)

SLASH PINE

Treatment[1/]	Front face						Backface	
	1944	1945	1946	1947	1948	1949	1950	1951
Weekly								
1/2 x 1/2 Untr.	166.6	175.0	206.1	232.9	247.4	229.9	150.2	176.5
Triweekly								
BC + Acid	124.9	126.2	146.2	100.3	162.4	160.8	123.7	150.0
LONGLEAF PINE								
Weekly								
1/2 x 1/2 Untr.	99.5	88.0	96.9	98.3	115.5	95.7	81.5	84.1
Triweekly								
BC + Acid	118.5	123.6	105.2	80.9	109.1	112.2	69.9	107.6

1/ Triweekly groups were bark chipped 3/4 inch high on front faces, , and 5/8 inch on back faces; a sulfuric acid concentration of 40 percent on slash and 60 percent on longleaf was used through 1949, and a 50-percent concentration for both species in 1950 and 1951.

The 8-year results in table 5 further strengthen the concept of no tree damage with the use of acid, shown in a successful 5 years of work with a biweekly schedule, previously reported (30). This test also gives us a preliminary indication that back-face yields with acid closely follow those of front faces.

Chipping Height

Observations on field procedures used in commerical operations show a wide difference in the height of bark chipping, with streak heights generally ranging from 1/2 inch to 1 inch. Chipping height is an important point of technique, and is influential in determining gum yields. No single height of bark chipping can be recommended for all situations. Evidence is available, however, that indicates the ideal height to use for specific circumstances (28,31).

A previous publication (32) discusses the relative differences in gum yield to be expected from different heights of bark chipping when acid is used on a 2-week schedule. The conclusions reached were: "....under average conditions of bark chipping and acid treatment on a 2-week schedule for a period of about 5 years, a chipping height of 1/2 inch is best. However, if trees are to be worked for a shorter period, or if a 3-week chipping and treating schedule is used on longleaf pine, the chipping height can be increased to 5/8 or 3/4 inch."

In general the data from another experiment, shown in table 6, tend to support this previous recommendation. In addition, further information on the intermediate chipping height of 5/8 inch is given. Under all the schedules used, gum yield increased progressively with height of chipping from 1/2 to 3/4 inch. These results are for a 3-year period only, however, and after two more seasons of work, the relationships might be slightly changed.

When we compare the yield results in table 6 for a triweekly schedule of bark chipping and acid treatment, with the old method of untreated deep chipping, a bark chipping height of 3/4 inch stands out as giving equivalent gum yields. This is a very important practical point because of the much greater efficiency obtained with a 3-week chipping and treating schedule. Thus, for those operators who have low nonlabor costs and who are interested in greatest net profits with a limited labor supply, a 3-week schedule of bark chipping and acid treatment at a chipping height of 3/4 inch is the best method to use.

For those operators interested in either prolonging the working life of a face or reducing the final height of this face, lower chipping heights of 1/2 or 5/8 inch will provide these results.

Width of Face

Under some conditions turpentine producers wish to get maximum yields in a relatively short time. One way they can do this is to speed up the frequency of chipping at the same time they increase chipping height. A more efficient method for them to use might be to maintain their present chipping frequency of every other week, but increase the width of the face and the height of chipping. This general recommendation was indicated by results of a previous experiment that ran for two years (31). Further data, with four seasons of work, are given in table 7.

The widest face used--2/3 circumference--was definitely not practical. At no time did yields from faces 2/3 circumference in width equal twice those from normal-width faces of 1/3 circumference. As a 4-year average, yields

Table 6.--Comparative gum yields with three different chipping heights

SLASH PINE

Treatment[1/]	Yield per crop				Relative yield
	1949	1950	1951	Average	
	Bbls.	Bbls.	Bbls.	Bbls.	Percent
Weekly untr. 1/2 x 1/2	178.7	203.9	217.8	200.1	100
Biweekly BC x 1/2	242.7	256.7	251.3	250.2	125
Biweekly BC x 5/8	258.4	263.6	256.4	259.5	130
Biweekly BC x 3/4	277.9	266.6	262.2	268.9	134
Triweekly BC x 1/2	151.9	164.7	186.4	167.7	84
Triweekly BC x 5/8	188.2	178.0	205.3	190.5	95
Triweekly BC x 3/4	200.7	202.4	231.7	211.6	106
LSD bbls per crop	48.8	53.8	57.1		

LONGLEAF PINE

Weekly untr. 1/2 x 1/2	164.6	137.2	129.0	143.6	100
Biweekly BC x 1/2	179.2	129.0	124.5	144.2	100
Biweekly BC x 5/8	211.2	148.5	148.9	169.5	118
Biweekly BC x 3/4	251.9	190.0	184.4	208.8	145
Triweekly BC x 1/2	127.4	106.3	101.8	111.8	78
Triweekly BC x 5/8	155.2	121.8	116.5	131.2	91
Triweekly BC x 3/4	165.3	140.8	126.5	144.2	100
LSD bbls per crop	38.8	34.9	30.6		

1/ All bark-chipped groups were treated with 50-percent sulfuric acid; all face widths 1/3 circumference.

Table 7.--Comparative gum yields at different chipping frequencies for 3 face widths

Treatment[1/]	Gum yield per crop					Relative yield
	1947	1948	1949	1950	Average	
	Bbls.	Bbls.	Bbls.	Bbls.	Bbls.	Percent
SLASH PINE						
Weekly (1/3 cir.)						
Untr. 1/2 x 1/2	212.7	220.7	221.8	227.4	220.6	100
Acid BC x 1/2	302.1	261.5	231.6	225.9	255.3	116
Biweekly (BC x 1/2)						
F.w. 1/3 cir.	207.0	230.9	212.3	210.5	215.2	98
F.w. 1/2 cir.	215.9	216.5	188.3	173.4	198.5	90
F.w. 2/3 cir.	287.7	316.4	267.1	250.5	280.4	127
Triweekly (BC x 1/2)						
F.w. 1/3 cir.	124.7	142.0	134.9	142.6	136.0	62
F.w. 1/2 cir.	162.1	182.6	172.0	173.9	172.6	78
F.w. 2/3 cir.	188.6	199.3	180.1	176.2	186.0	84
LSD bbls per crop	39.2	44.8	58.3	62.3		
LONGLEAF PINE						
Weekly (1/3 cir.)						
Untr. 1/2 x 1/2	141.7	137.1	140.0	131.3	137.5	100
Acid BC x 1/2	268.3	227.4	199.7	172.8	217.0	158
Biweekly (BC x 1/2)						
F.w. 1/3 cir.	161.8	150.7	152.8	135.2	150.1	109
F.w. 1/2 cir.	201.0	190.6	196.5	173.6	190.4	138
F.w. 2/3 cir.	241.2	229.8	213.2	189.2	218.4	158
Triweekly (BC x 1/2)						
F.w. 1/3 cir.	116.0	122.4	108.3	101.9	112.2	82
F.w. 1/2 cir.	164.9	157.2	145.4	127.3	148.7	108
F.w. 2/3 cir.	171.7	168.8	145.4	128.6	153.6	112
LSD bbls per crop	28.9	36.6	50.2	46.5		

1/ In 1947-9 inclusive a 40-percent concentration of sulfuric acid was used for slash and a 60-percent concentration for longleaf; a 50-percent solution was used for both species in 1950. "F.w. ( ) cir." indicates the face width as a fraction of the circumference.

from double-width faces were only 30 and 46 percent greater than faces of normal width on a biweekly schedule for slash and longleaf, respectively, or 37 percent greater on a triweekly schedule for both species. The highest relative difference was 51 percent for the first year in the slash pine triweekly groups. This amount of increase is probably not sufficient to meet the increased chipping and tin installation costs of the wider faces. In general yields from double-width faces declined moderately for all groups during the 4 years of work.

The yield relationships for faces 1/2 circumference in width were much more favorable from a practical standpoint. Except for the biweekly slash groups, yields averaged nearly 30 percent greater for faces 1/2 circumference in width than those 1/3 circumference. Since increased tin-installation costs would be relatively small on 1/2 circumference faces, and chipping costs could be expected to be only slightly greater, this method offers promise in increasing yields and profits. However, the use of faces 1/2 circumference in width would mainly be limited to circumstances where only one face was to be turpentined just prior to harvesting of the tree.

Another factor to consider is that similar yield increases approximating 30 percent could be obtained by merely increasing the chipping height from 1/2 inch, as used in this study, to 3/4 inch on faces 1/3 circumference in width. Obvious advantages are offered by the latter method, even though the ultimate total face height would be somewhat greater. However, further augmented yields might be obtained by using a 3/4-inch chipping height on faces 1/2 circumference in width. An experiment with the partial objective of determining whether this was true is reported in table 8.

These results show that a chipping height of 3/4 inch did not materially increase yields from faces 1/2 circumference in width. This was an unexpected result, since we previously thought that yields might be increased in faces 1/2 circumference in width if greater chipping heights were used. With the 1/3 circumference faces, however, yields were greater with increased chipping height. It is possible that the "treatment intensity" level of faces 1/2 circumference in width is such that physiologically the tree is not capable of sustaining a further yield increase that might be induced by a greater chipping height. This evidence further supports the conclusions reached in the discussion under the heading "Diameter" concerning the maximum yield level capability of a tree.

Number of Faces

When more than one face is placed on a single tree, the actual costs of operation are almost the same as if these extra faces were on other trees. Consequently, when determining the efficiency of any multiple cupping method, the yield per face is the important factor. Earlier studies (28,31) explored the possibilities of more than one face per tree. In spite of very large initial yields from trees with many faces, maximum sustained yields were uniformly obtained from trees with no more than two faces for a 2-year period. One of these studies in which tree diameters ranged from 9 to 13 inches b.h., was continued for an additional 2 years of work. Results are shown in table 9.

Table 8.--Comparative gum yields for trees with different frequencies of chipping, height of chipping, and width of face

(In barrels per crop)

Treatment[1]		Average gum yield per crop[2]	
		Slash	Longleaf
Weekly Untr. 1/2 x 1/2		191.3	150.9
Biweekly			
	BC x 1/2	249.7	154.1
F.w. 1/3 cir.	BC x 5/8	261.0	179.8
	BC x 3/4	272.2	221.0
	BC x 1/2	312.0	201.1
F.w. 1/2 cir.	BC x 5/8	290.2	223.6
	BC x 3/4	289.2	214.8
Triweekly			
	BC x 1/2	158.3	116.8
F.w. 1/3 cir.	BC x 5/8	183.1	138.5
	BC x 3/4	201.6	153.0
	BC x 1/2	218.7	172.3
F.w. 1/2 cir.	BC x 5/8	215.3	165.6
	BC x 3/4	225.8	171.1

1/ All groups treated with 50-percent sulfuric acid except the trees on a weekly schedule, which were untreated. "F.w. ( ) cir." indicates the face width as a fraction of the circumference.

2/ Average for 2 years of work.

Although 2-year yields were good, the yield per face (two-faced, acid-treated trees), compared to a single face on untreated controls, fell off considerably the fourth year, being 32 and 39 percent lower for slash and longleaf respectively. Yields the first 3 years averaged 1 percent greater for each face in slash, and 15 percent greater in longleaf, for the trees receiving weekly acid treatment and bark chipping. The 4-year average was 10 percent less for slash pine and 2 percent more for longleaf.

A realistic look at the gum-yield figures in table 9 shows that yield totals, on which potential practical methods must be based, were higher for each of the treated faces on double-cupped trees for only 2 years in slash and 3 years in longleaf. Thus, if weekly chipping can be practiced, it might be possible to work profitably two faces with bark

Table 9.--Gum yields from single- and double-faced trees

SLASH PINE

Treatment[1]	No. of faces	Gum yield per crop[2]				
		1945	1946	1947	1948	Average
		Bbls.	Bbls.	Bbls.	Bbls.	Bbls.
Untr. 1/2 x 1/2	1	155.6	179.2	198.1	239.8	193.2
Acid BC x 1/2	2	181.6	185.5	168.9	162.0	174.5

LONGLEAF PINE

Untr. 1/2 x 1/2	1	144.5	153.1	152.1	195.3	161.3
Acid BC x 1/2	2	191.1	175.6	152.6	138.8	164.5

1/ Face-width 1/3 circumference on single-face trees; 4/10 circumference each on two-face trees. A weekly chipping schedule was used.
2/ Yield per crop of faces (10,000).

chipping and acid treatment for 2 years in slash pine and 3 years in longleaf pine. However, since a 2-week chipping and treatment schedule is much more efficient, it is doubtful whether the average stand of turpentine timber, with diameters averaging 10.5 inches, should be cupped with two faces per tree, since the yields per face tend to be marginal on a 2-week schedule.

The best information we have to date on the lowest diameter tree that can profitably be worked with two faces is contained in the discussion of "Diameter" in this paper. Here, it appears that two faces on trees larger than 13 inches constitute a good method to use if a biweekly schedule of bark chipping with acid treatment is followed.

Split Faces

Observation shows us that gum flow is greatest from the portion of the streak near the shoulder, and least from the portion near the center of the face. We can easily postulate a physiological basis for this fact. Lowered activity near the center of the face may result from decreased available quantities of water, mineral elements, and transported carbohydrates used as gum precursors.

In order to overcome these possible deficits, we thought that by decreasing the face width by one-half and providing a live bark-bar between these smaller faces increased gum yields might be obtained. However, experimental studies have been contradictory and further testing is necessary.

From a practical standpoint, tin installation costs are only slightly increased for split-face work, since a single cup and gutter installation can be used (9). However, in the initial stages of field work, increased supervision (8) is needed to train the laborers to keep the bark-bars intact, the face widths uniform, and the side lines vertical.

Acid Concentration

Early experiments in the use of sulfuric acid were made with low concentrations of 5 to 20 percent by weight (13). Later work showed that a 40-percent concentration was effective on slash pine, but did not produce expected results on longleaf (14,15). Further research revealed that at a concentration of 60 percent longleaf responded favorably (28).

As slash and longleaf often are included in a single drift, this posed a difficult treatment problem, since it was not feasible to carry two spray bottles at the same time, each with a different acid concentration. Also, optimum yields would never be obtained in mixed stands when either strength of acid was used alone. Thus there was need for a single acid concentration of maximum effectiveness for both species. The study summarized in table 10 was conducted to solve this problem.

These results show that a sulfuric acid concentration of 50 percent works equally well for both slash and longleaf pine over a 5-year period. On the average, the yields from trees treated with a 50-percent acid concentration were slightly greater for each species than the yields from trees receiving the formerly recommended concentrations of 40 percent for slash and 60 percent for longleaf pine.

No further refinements in acid concentration appear necessary, since yield variations due to amount of acid applied could be greater than any yield change due to a slightly different acid concentration. From a practical standpoint it is important to obtain uniform coverage of the entire freshly cut streak with the correct amount of acid (26). This amount will change to meet varying needs of weather and stand conditions. The quantity of acid should be reduced during dry spells, particularly on the poorer sites with crowded stand conditions, and with over-mature trees with small crowns. A healthy, vigorously growing tree with adequate moisture should receive the equivalent of 1 cc. of acid per 8 inches of face width (17).

Other Chemicals

Of the many different chemicals tested since the last comprehensive report on chemical stimulants (31), only 2,4-D (2,4-dichlorophenoxyacetic acid) has offered any real promise as a substitute for sulfuric acid. A noncorrosive chemical such as 2,4-D would be much safer to use, and would eliminate the necessity of acid-proof equipment.

Briefly, it should be emphasized now that, although 2,4-D appears satisfactory for use on pure slash pine according to the latest studies, 2,4-D is not recommended for general use, particularly in longleaf, as excessive mortality occurs in longleaf pine stands turpentined with the use of 2,4-D.

Table 10.--Gum yields from trees treated with different concentrations of sulfuric acid

SLASH PINE

Treatment[1]	Gum yield per crop[2]						Relative yield
	1947	1948	1949	1950	1951	Average	
	Bbls.	Bbls.	Bbls.	Bbls.	Bbls.	Bbls.	Percent
Weekly (1/3 cir.)							
Untr. 1/2 x 1/2	183.8	200.1	235.2	276.9	240.3	227.3	100
40% Acid BC x 1/2	287.2	255.5	237.7	241.3	224.3	249.2	110
50% Acid BC x 1/2	332.0	296.6	288.6	280.7	251.5	289.9	128
Biweekly (1/3 cir.)							
40% Acid BC x 1/2	230.2	254.7	259.4	251.0	232.8	245.6	108
40% Acid BC x 3/4	257.8	272.2	250.3	223.4	216.3	244.0	107
50% Acid BC x 1/2	217.1	214.4	220.8	206.5	179.0	207.6	91
50% Acid BC x 3/4	270.6	308.0	282.2	263.2	246.7	274.1	120
LSD bbls per crop	57.1	65.3	63.8	70.8	87.3		

LONGLEAF PINE

Weekly (1/3 cir.)							
Untr. 1/2 x 1/2	125.3	128.5	133.2	135.7	104.4	125.4	100
50% Acid BC x 1/2	205.1	187.7	186.1	149.8	130.4	171.8	137
60% Acid BC x 1/2	211.3	199.9	191.2	145.2	139.8	177.5	142
Biweekly (1/3 cir.)							
50% Acid BC x 1/2	142.2	139.9	139.1	118.6	112.4	130.4	104
50% Acid BC x 3/4	183.6	193.8	181.0	149.9	134.4	168.5	134
60% Acid BC x 1/2	114.5	125.2	117.9	98.5	92.5	109.7	87
60% Acid BC x 3/4	141.8	164.5	164.5	131.4	130.7	146.6	117
LSD bbls per crop	51.4	37.4	37.4	35.8	32.1		

1/ Sulfuric acid used.
2/ Yield per crop of 10,000 faces.

Early experiments, summarized in table 11, indicated that at concentrations of 4 or more percent, solutions of 2,4-D do not result in yields equal to those from sulfuric acid treatment in either slash or longleaf pine. Even with a "biweek-skip" system of treatment (chip every second week and treat every fourth week), which is one of the least intensive used in our experiments, 20 percent of the treated longleaf trees died. Even higher percentages of loss occurred in some of the other 2,4-D treatment groups, with some longleaf trees dying the following year. These 1948 results definitely indicated that the concentration was too high, and was particularly unsuited for longleaf.

Table 11.--Comparative gum yields for trees treated with different chemicals at various concentrations

Treatment[1/]	SLASH		LONGLEAF	
	Yield	Relative yield	Yield	Relative yield
	Bbls.	Percent	Bbls.	Percent
Weekly				
Untr. 1/2 x 1/2	297.2	100	162.0	100
Biweekly				
50% sulfuric acid	237.1	80	186.0	115
20% sulfamic acid	241.2	81	99.3	61
4% 2,4-D	241.2	81	115.5	71
6% 2,4-D	259.5	87	115.4	71
8% 2,4-D	253.2	85	102.0	63
Biweekly-skip[2/]				
6% 2,4-D[3/]	226.2	76	126.3	78
8% 2,4-D[3/]	264.4	89	131.5	81
LSD bbls per crop	60.5		34.4	

1/ Results for 1948. All treated groups were BC x 1/2 except the group with dust treatment, which was BC x 3/4. Yield per crop of 10,000 faces.

2/ Chipping every second week and treating every fourth week.

3/ Last 20 weeks of season pure 2,4-D dust was used, instead of the 8-percent 2,4-D solution, on a biweekly schedule.

In 1949 a small study of weaker 2,4-D concentrations was started in slash pine. The 3-year data summarized in table 12 show that a 2-percent 2,4-D treatment resulted in consistent yields for the entire period, essentially equivalent to those to be expected from sulfuric acid treatment. This encouraging trend suggested that some of the weaker 2,4-D concentrations might be suitable for longleaf, and some intermediate concentration even better for slash pine.

Close examination of the relative yields from the different treatments shows that the yields from those with the weakest concentration (table 12) were about 20 percent less than the controls. This level is about what one would expect from untreated bark chipping. Thus we could conclude that at a concentration of 0.5 percent the 2,4-D had no effect on yields. Also, since a 1.0-percent concentration resulted in yields about the same as the deep-chipped controls, particularly the first year, this concentration had a slight effect on yields.

Table 12.--Comparative gum yields for trees treated with different concentrations of 2,4-D

SLASH PINE

Treatment	Gum yield per crop[1]				Relative yield
	1949	1950	1951	Average	
	Bbls.	Bbls.	Bbls.	Bbls.	Percent
Weekly (1/2 x 1/2)					
Untreated	176.0	206.8	223.4	202.1	100
Biweekly (BC x 1/2)					
0.5% 2,4-D	144.0	173.3	165.4	160.9	80
1.0% 2,4-D	178.2	191.8	186.2	185.4	92
2.0% 2,4-D	243.1	254.5	239.0	245.5	121
LSD bbls per crop	31.8	41.0	43.1		

1/ Yield per crop of 10,000 faces.

Results of an experiment incorporating a wide range of treatments with 2,4-D solutions in concentration steps of 0.5 percent are given in table 13. These data show that for the 2-year period a 2-percent 2,4-D solution was best in slash pine. This substantiates the results of the study reported in table 12. These data also show again that 2,4-D in all the concentrations used does not produce a satisfactory yield response in longleaf. In addition, up to 40 percent of the longleaf trees died in some of the groups.

Table 13.--Comparative gum yields for trees treated with different concentrations of 2,4-D and worked by several methods

SLASH PINE

Treatment[1/]	Yield per crop			Relative yield
	1950	1951	Average	
	Bbls.	Bbls.	Bbls.	Percent
Weekly				
Untr. 1/2 x 1/2	184.9	188.9	186.9	100
Biweekly (BC x 5/8)				
50% Acid	216.4	194.5	205.4	110
0.5% 2,4-D	164.4	168.0	166.2	89
1.0% 2,4-D	212.8	210.5	211.6	113
1.5% 2,4-D	207.3	--	--	--
2.0% 2,4-D	250.4	233.4	241.9	129
2.5% 2,4-D	225.8	--	--	--
3.0% 2,4-D	230.2	227.1	228.6	122
Split face (Bwkly)				
50% Acid BC x 5/8	309.5	289.4	299.4	160
1.5% 2,4-D BC x 5/8	244.7	268.6	256.6	137
LSD bbls per crop	43.7	55.2		

LONGLEAF PINE

Weekly				
Untr. 1/2 x 1/2	160.9	158.2	159.6	100
Biweekly (BC x 5/8)				
50% Acid	177.3	152.0	164.6	103
0.5% 2,4-D	121.9	--	--	--
1.0% 2,4-D	119.7	--	--	--
1.5% 2,4-D	122.2	--	--	--
2.0% 2,4-D	112.2	--	--	--
2.5% 2,4-D	120.5	--	--	--
3.0% 2,4-D	123.1	--	--	--
Split face (Bwkly)				
50% Acid BC x 5/8	188.4	190.3	189.4	119
1.5% 2,4-D BC x 5/8	131.0	--	--	--
LSD bbls per crop	39.8			

1/ Sulfuric acid used.

Although 2,4-D offers promise as a substitute for sulfuric acid in treating slash pine, from a practical standpoint industry is not urged to try this chemical, even for slash pine. The main reason for this caution is the fact that 2,4-D causes excessive mortality when applied to longleaf streaks, and indiscriminate use by unskilled labor would inevitably lead to longleaf trees being treated. Treatment of these longleaf with 2,4-D will lead to the early death of up to 50 percent or more of the trees. Work on suitable 2,4-D treatment methods for longleaf pine is under way. Until a safe method is found for longleaf, 2,4-D is not recommended for general use in turpentining. Sulfuric acid still remains the best chemical to use.

Year of Work

Commonly in the past, yield declines have been noted in the latter years of working a face. Most of this decline has been associated with deep incisions, with the greatest decline noted (16) in the days of the cut box. Even with broadaxe incisions, decreases in yields occurred in successive years of work. Wyman (38) indicated that gum yields from longleaf pine trees declined about 30 percent in 5 years, or an average of 6 percent annually; yields in slash pine fell off slightly more. In other tests, with careful gutter insertions (1), yield declines were less; in fact, second year yields were often higher than those of the first year, with only a 10-percent drop in the 5 years of work.

A different picture is presented when modern turpentine methods are used. In almost all the experiments reported in this paper the tins were fastened on to the outside of the wood or smoothed bark with no insertions. As a consequence, none of the data showed consistent annual yield declines over long periods, except for those treatments that were definitely too intensive in character.

The differences observed can generally be attributed to specific causal agents, as previously discussed where pertinent. The causes include such factors as drought, insect depredations, and particularly the intensity of the specific treatment used. Thus, no clear-cut simple statement can be made to answer the general question of how yields vary in successive years of turpentining with bark chipping and sulfuric acid treatment. We do know, however, that conservative tin installation methods and conservative treatments lead to a fairly sustained level of yield over a number of years of work.

Winter Work

Many producers would like to have a winter income to help defray the carrying costs of the many winter jobs that have to be done, and to help keep a working group intact. One solution to this problem, when the old method of deep chipping was used, was a monthly streak applied between regular seasons. Yields were fair with this system. More recently some operators have used acid intermittently during the winter, and many have asked whether this practice is sound.

For two reasons we have previously advised against winter work with acid (34). First, poor yields have resulted in early experiments with weekly chipping and treatment on a continuous schedule through the winter

and the following season (25,28,34). Second, acid-killing of tissues above the face (25,27) has been excessive when this tissue is allowed to remain undisturbed for 4 weeks, and subsequent yields have been lower. However, we then lacked data on yields from winter work with other chipping schedules. A recent experiment gave us some preliminary information on other chipping and treatment schedules. This data is summarized in table 14.

Table 14.--Relative gum yields from longleaf worked in winter

Basic treatment	Yield in 1950	Winter yield[1]	Yield in 1951	'51 yield as percent of '50	Theoretical yield based on control[2]	Winter yield plus 1951 yield
	Bbls.	Bbls.	Bbls.	Percent	Bbls.	Bbls.
Wkly. Untr.	131.3	--	118.2	90.0	118.2	118.2
Wkly. Acid	172.8	12.8	125.7	72.7	155.5	138.5
Bwkly. Acid	135.2	17.7	104.0	76.9	121.7	121.7
Twkly. Acid	101.9	18.9	72.2	70.8	91.7	91.1
LSD bbls per crop	46.5		32.0			

1/ The untreated group was rested during the winter; other groups were on a triweekly bark chipping schedule with acid during the winter; in 1951 regular treatments were resumed.

2/ Yields of treated groups are in the same proportion to the 1950 yields as those of the untreated control group which rested during the winter, and represent the theoretical yields assuming normal winter rest and uniform seasonal fluctuation.

Several important trends are evident from these results. First, yield declines in all groups worked during the winter were greater than the seasonal fluctuation shown by the control group. In other words, winter work caused a decrease in yields during the next regular season of work. Second, this decrease in yields is equalized by adding winter yields to those of the following season in groups on a biweekly and triweekly schedule, but not in the group on a weekly schedule. This indicates that a weekly chipping and treatment schedule may be too severe to be maintained over successive years of work. This confirms results of other experiments (31). However, the lower yields of the weekly group in 1951, when compared to 1950, may also have been due in part to the usual decline in yields from year to year at this chipping frequency, which was increased by winter work.

Although the total of winter and 1951 season's yields approach those that might be expected from trees with a winter rest period, the added costs of chipping and treating during the winter place winter working in a more doubtful position.

If the efficiency of each type of treatment is considered, the yields in table 15 will give some indication of the relative value of each method.

Table 15.--Relative gum yields from longleaf for the data in table 14

Basic treatment[1/]	Gum yield per streak per 1,000 faces		
	1950	Winter	1951
	Bbls.	Bbls.	Bbls.
Weekly untreated	0.41	--	0.37
Weekly acid	.54	0.26	.39
Biweekly acid	.84	.35	.65
Triweekly acid	.92	.38	.66

1/ The untreated group was rested during the winter; other groups were on a triweekly bark chipping schedule with acid during the winter; in 1951 regular treatments were resumed.

It is quite obvious that for the labor expended, yields from triweekly chipping during the regular season are the highest. But to meet the requirements of fixed costs, greater total yields for the season (table 15) may be considered more important, which would make the biweekly schedule more attractive when considered from both standpoints.

Although the general yield level for this longleaf plot is low, it is still about the same as that obtained in some of the commercial operations in this area, and winter yields per streak are not far from those using weekly untreated chipping. So, from this standpoint, winter working may be practical, but the efficiency is not as great as could be desired.

The problem of winter work becomes increasingly important as more and more producers change over to the use of bark chipping and acid. Many of these new acid users previously have done winter work with untreated deep chipping as a regular part of their yearly schedule. They will be faced with the immediate problem of deciding whether to do winter work when using bark chipping and acid. To date we do not have a clear-cut answer to this problem. But we do know that equivalent yields are obtained with a 3-week winter schedule with acid, that the following year's yields are somewhat reduced because of winter work, and that the over-all efficiency is lower. To balance these latter drawbacks, we have the benefits of keeping a working crew together, and there is a small winter income for the producer to use in defraying other winter costs. Further intensive studies on this problem are under way to provide more basic data on the relative merits of winter work.

Clean-up Streak

When trees are treated with acid, it is necessary to remove the acid-killed tissue that results from the last treated streak of the season before maximum yields can be obtained during the first part of the next season's work. This may be done either in the fall or as part of the initial spring operation, provided the trees are rested during the winter. Either time of doing this necessary task has both advantages and disadvantages, as previously discussed (35).

An untreated streak put on in the fall removes acid-killed tissue above turpentine faces and helps to provide early gum yields from the first treated streak put on the following spring. Schopmeyer (27) concluded that the fall clean-up streak simplified labor supervision, and that a lower clean-up streak was needed in the fall than in the spring, particularly in longleaf. However, gum yields from untreated clean-up streaks in the fall are very low, and it may be difficult to persuade laborers to make this bark-chipped streak if they are being paid on a rental basis.

As indicated before (35) the average height of a clean-up streak, when made in the fall, is close to 1 inch for both slash and longleaf. This conclusion is based on 2500 observations made in two different seasons. The range of heights needed to reach clear white wood, among the many individual trees tested, varied from as little as 1/2 inch to as much as 1-1/2 inches. Of the many types of treatments sampled, no great difference in the average required chipping heights for the clean-up streak was found because of acid concentration, height of chipping, width of face, or tree diameter.

If the producer elects to make a combination spring clean-up streak and initial treated streak, the chipper should chip at least a double streak. In slash pine two full hack streaks with a 1/2-inch bark hack will be sufficient to remove most of the killed tissue. In longleaf most killed tissue can be removed with two full streaks with a 5/8-inch bark hack.

Although a greater height of tissue must be removed in the spring than in the fall, the fall clean-up streak still requires double chipping in most cases. The only difference is that in the fall two streaks, each less than the full width of the hack, are made, while in the spring two full hack streaks are needed. Thus no saving in labor is obtained by making the clean-up streak in the fall rather than in the spring.

The strongest single argument for a spring clean-up streak is the much greater yields obtained then because of the acid applied to this streak. In comparison, low yields are obtained after a fall clean-up streak because no acid can be applied then without defeating the purpose of the clean-up streak. A chipper working on a rental basis would be more inclined to favor spring for the clean-up streak in view of the greater yields obtained.

Either of these methods will achieve the end objective of increased gum yields with the minimum of expended effort. The final choice of method rests with the producer, who knows which will best fit his own operating conditions.

Effects of Fertilizers on Yields

Some stands of turpentine pine yield more gum than others. One of the several factors responsible for this difference is nutrition. We have previously believed, but lacked proof, that better soil fertility conditions resulted in greater gum yields. Our belief has been substantiated by the experiment summarized in table 16 and figure 5.

Table 16.--Relative gum yields from slash pine trees in different yielding groups with and without fertilizer treatment

Treatment[1]	Yield level	Gum yield per crop[2]					Relative yield
		1946	1947	1948	1949	Average	
		Bbls.	Bbls.	Bbls.	Bbls.	Bbls.	Percent
Fertilized	High yielder	390.2	455.2	500.0	452.2	449.4	124
	Average yielder	377.4	427.3	509.1	519.5	458.3	126
	Low yielder	264.8	330.6	411.6	408.4	353.8	97
Not fertilized	High yielder	350.0	381.1	406.4	400.3	384.4	106
	Average yielder	318.6	352.8	400.7	382.6	363.7	100
	Low yielder	214.8	265.7	307.5	313.0	275.3	76
LSD bbls. per crop		137.6	190.5	197.0	192.4		

1/ All trees were bark chipped weekly and treated with sulfuric acid.
2/ Yield per crop of 10,000 faces.

The slash pine trees in this experiment were growing in an old field. They had large crowns and were not crowded. Before fertilizer was applied, all trees whose crown extensions were within 8 feet of the crowns of the experimental trees, were removed. A complete NPK fertilizer plus minor essential elements was applied three times each year at a total yearly rate of 500 pounds of nitrogen per acre. Our primary object was to demonstrate a possible effect, not delimit an optimum fertilizer treatment. Our secondary object was to determine whether trees of different yielding abilities responded the same to applied fertilizers.

The average yearly increase in gum yield due to fertilizer treatment was about 25 percent (significant at 5-percent level). This amount is substantial, and could well be worthwhile if the cost of fertilizer application was kept low. Determination of the correct amount of fertilizer that would prove practical will have to await results of future studies.

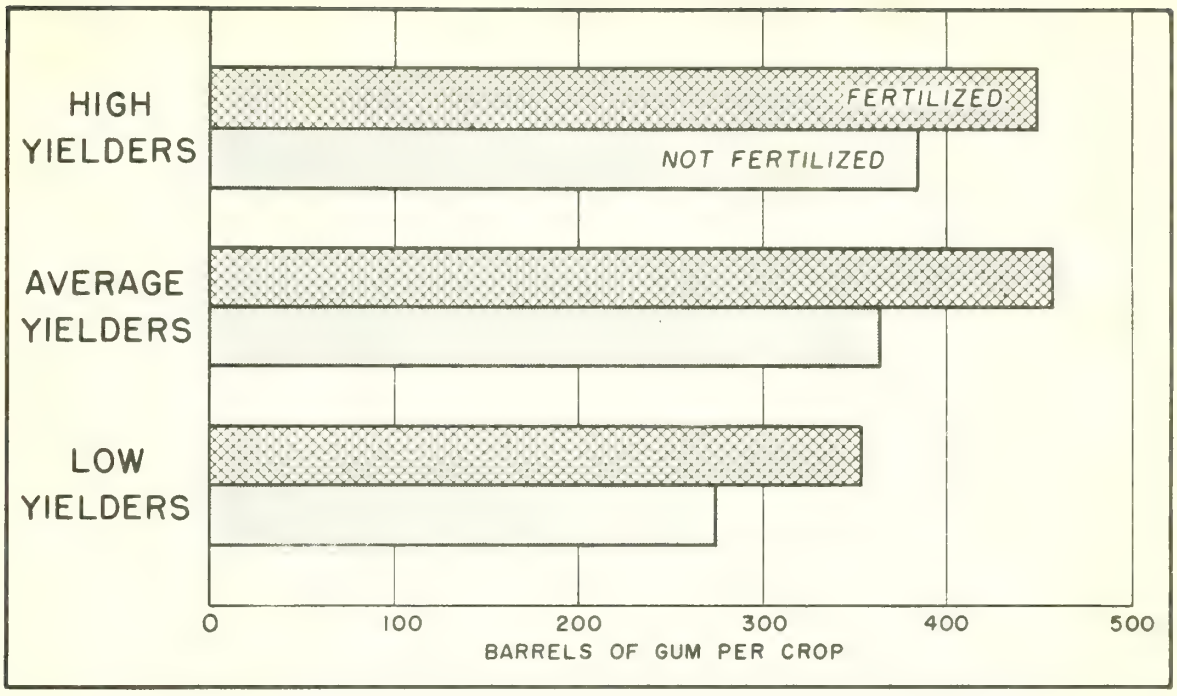


Figure 5.--Effect of fertilizing on gum yields from trees of different yielding abilities (average annual yield for 4 years of work).

Analysis of the total gum yields for the 4 years of turpentining revealed that the superiority of yields from the fertilized trees was statistically significant.

The high yields in this study, which were more than double those normally obtained, may be attributed to two factors. First, acid treatment was on a weekly basis, the most intensive that we use. Second, the trees all had large crowns, and all competing trees were removed from around each study tree.

It was expected that with the intensive treatment used, yields would decline after several years of work in the group with no fertilizer applied, while keeping relatively constant in the fertilized groups. This was not the case, since yields generally increased in both groups for the entire 4-year period. This may have been due to the fact that the trees were capable of this sustained high drain because of their excellent crowns and freedom from competition.

SUMMARY

Various modifications of potentially practical methods of turpentining, using bark chipping and acid treatment, have been studied at the Lake City, Florida, Research Center. The results of these studies for the past 5 years are given in this paper, and the relative merits of each method discussed. Briefly, some of the important conclusions of these studies from 1947 through 1951 are as follows:

1. Attaching tins on the surface of smoothed bark resulted in 12 and 35 percent more gum (slash and longleaf respectively), than when tins are inserted in the tree with a broadaxe. This result was obtained in trees bark-chipped and treated with acid, and confirms the same result obtained in earlier work with untreated deep chipping.

2. With weekly untreated deep chipping, gum yields increased with increase in tree diameter from 9.0 to 13.9 inches d.b.h. When trees were bark chipped and acid treated on a 2-week schedule, yields also increased with diameter, but the peak was apparently reached in the 12.0- to 12.9-inch class. It was also found that per inch of face width yields followed the same trend as mentioned above, with larger trees capable of yielding more gum per inch of face width.

3. The greatest relative yield increase due to acid treatment was noted in the lower-yielding groups of trees. The least response was found in the high-yielding groups, probably because they were already near their possible peak of sustained gum production.

4. For maximum gum production with good efficiency, a schedule of bark chipping and acid treatment every 2 weeks is best. A 3-week schedule is the most efficient chipping and treatment method, but the level of gum production falls to about that obtained with weekly untreated deep chipping.

5. A bark chipping height of 3/4 inch is best when a 3-week working schedule is used. For a 2-week schedule, a chipping height of 1/2 or 5/8 inch will give good yields and prolong the working life of the face, as well as reduce the final face height.

6. Face widths of 2/3 circumference are not practical. However, a face width of 1/2 the circumference will result in a 30-percent increase in yield over that from faces 1/3 circumference in width on average-size trees for a 2-year period. This latter method is recommended only where a single face is to be used just prior to harvesting the tree.

7. No more than two faces should be used simultaneously on a single tree. With weekly bark chipping and acid treatment, profitable yields were obtained from two-faced trees for 2 years in slash, and 3 years in longleaf pine. With a two-week chipping schedule, which is the general recommended procedure, it is doubtful whether two faces should be used on average-sized trees. With acid treatment the smallest tree that would profitably support two faces is probably about 13 inches d.b.h.

8. Split faces each 1/6 circumference in width and separated by a 2-inch bark-bar offer promise as a new turpentining method. Yield increases of 46 and 15 percent were obtained with split faces over a 2-year period for slash and longleaf respectively.

9. A sulfuric acid concentration of 50 percent proved best for both slash and longleaf over a 5-year period.

10. Preliminary tests indicated that a 2-percent 2,4-D solution resulted in yields equal to those obtained with sulfuric acid treatment when applied on slash pine. However, because low yields and excessive tree killing occurred when longleaf pines were treated with 2,4-D, this chemical is not recommended for general use.

11. Gum yields do not decline in successive years of work when trees are turpentined by bark chipping and acid treatment on a 2-week schedule. With weekly acid treatment, yields decline in succeeding years.

12. Sufficient evidence is not available to recommend winter work as standard practice when bark chipping and acid treatment is used. A 3-week winter schedule barely paid its way, resulted in reduced yields the next season, and was not efficient. To balance these drawbacks there were the advantages of a winter income and retention of labor force.

13. Spring is the favored time for a clean-up streak to remove acid-killed tissue, mainly because of greater yields obtained then, compared to negligible yields from an untreated clean-up streak in the fall.

14. Fertilizing trees definitely increases gum yields. Optimum fertilizer treatments have not yet been determined.

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Agriculture-Asheville

STATION PAPER NO. 33 JANUARY 1954

INSTRUCTIONS FOR USING FOREST FIRE DANGER METER TYPE 8

by

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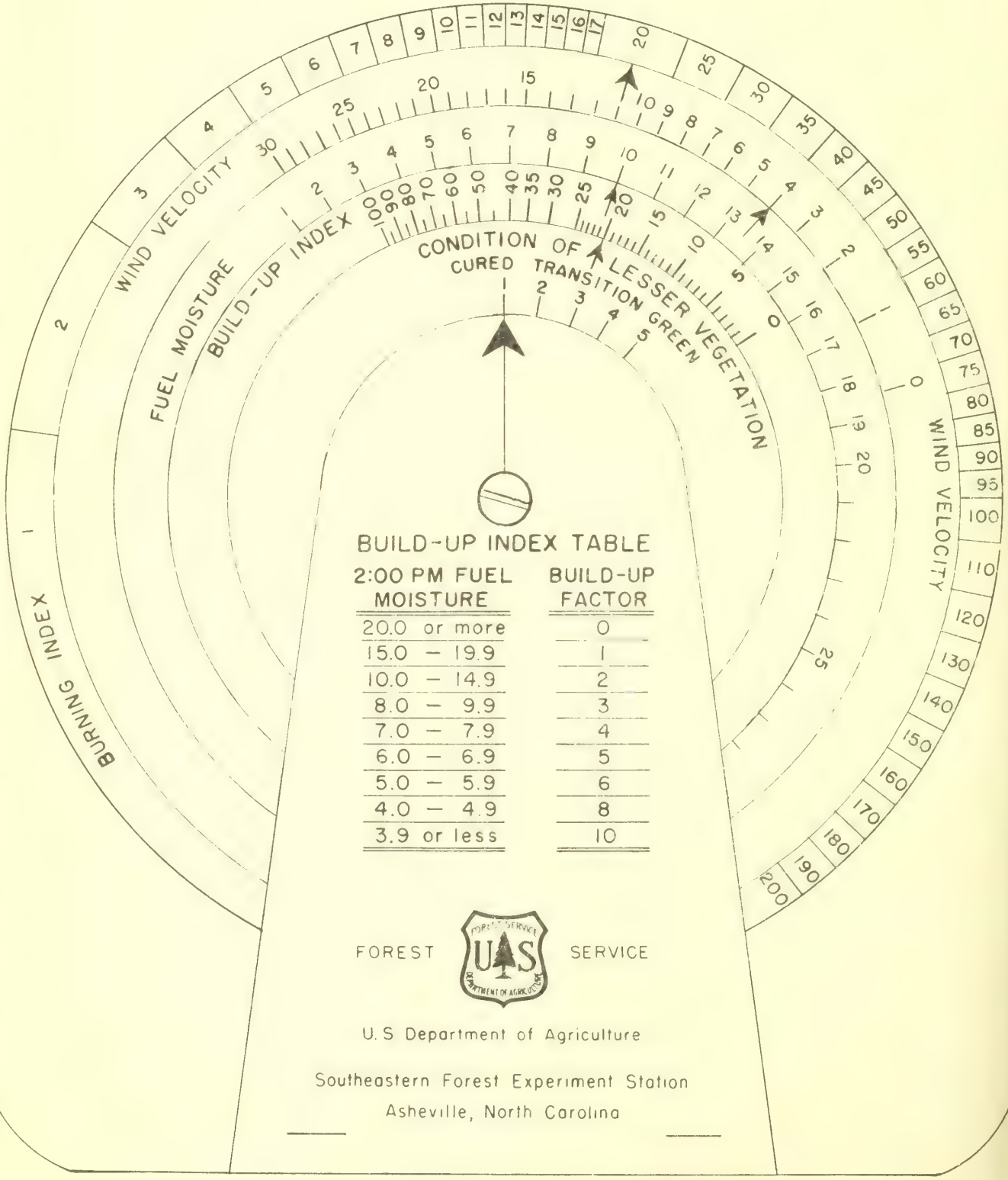
FOREST SERVICE
SOUTHEASTERN FOREST EXPERIMENT STATION
Asheville, North Carolina
E. L. Demmon,
Director

FOREST FIRE DANGER METER TYPE 8-W



BUILD-UP INDEX TABLE

2:00 PM FUEL MOISTURE	BUILD-UP FACTOR
20.0 or more	0
15.0 – 19.9	1
10.0 – 14.9	2
8.0 – 9.9	3
7.0 – 7.9	4
6.0 – 6.9	5
5.0 – 5.9	6
4.0 – 4.9	8
3.9 or less	10

FOREST SERVICE

U.S Department of Agriculture

Southeastern Forest Experiment Station

Asheville, North Carolina

INSTRUCTIONS FOR USING FOREST FIRE DANGER METER TYPE 8

by

John J. Keetch[1/]

INTRODUCTION

The following instructions apply to meter 8-W (woods-type station), and to meter 8-0 (open-type station), issued by the Southeastern Forest Experiment Station. These meters replace types 5-W and 5-0, in U. S. Forest Service Region 7 territory, effective January 1954. The shift in fire danger meters has been approved by the Regional Forester for use on national forests, and by the State Foresters at their June 1953 meeting in Philadelphia.

The changes incorporated in meter 8 were suggested by experienced fire control officers throughout the region who wanted a more consistent meter, particularly with respect to the fire danger build-up during drought periods. Also, a meter was wanted that did not overrate periods of sub-normal fire danger when days are relatively cool and intermittent light showers occur. Briefly, meter 8 retains the same basic factors as meter 5, but differs in three respects: (1) a "Build-up Index" disc replaces the discs on the type 5 meters representing season of the year, last rain in inches, and days since rain; (2) condition of vegetation has 5 settings instead of the former 3; and (3) the burning index scale, which is identical with the type 5 meters from 1 to 100, has been extended to 200. The extension was made so that stations in a district network having readings above 100 could be more accurately averaged when computing the district burning index.

During periods of "normal" fire danger, meter 8 will give approximately the same burning index as the type 5 meters. During easy fire weather, the daily burning index will be lower. When extended droughts occur, or shorter periods of hot, dry weather, the burning index will usually be higher--up to 150 percent of meter 5.

Because of these changes in the fire danger factors, the instructions discussed in this paper and the revised form for recording daily fire danger must be used with meter 8. There has been no change in the standards for selecting danger station sites, or for installing and maintaining the fire danger equipment. These standards, and the procedures to be followed in taking the measurements of wind velocity, fuel moisture, and rain, are described in USDA Handbook No. 1 and Southeastern Station Technical Note No. 71.

1/ Forester (Fire Control), USDA, Forest Service, Region 7, Division of State and Private Forestry.

Form 14-R-7 (Rev. Jan. 1954) FIRE DANGER DAILY RECORD April (month) 1952

Sample (State or Forest) Sample (District) Sample (woods-type) (Station) John Doe (Observer)

Day of the Month	Condition of the Lesser Vegetation	9 A.M. EST			24 HOUR RAINFALL 2 P.M. TO 2 P.M. (Hundredths)			2 P.M. EST					5 P.M. EST			Highest Burning Index for the Day
		Fuel Moisture Percent	Wind Velocity Miles per Hour	Burning Index	Amount of Rain Danger Station	Amount of Rain Coop. Station	Average Amount of Rainfall	Build-up Index March 31 = 36	Build-up Factor	Fuel Moisture Percent	Wind Velocity Miles per Hour	Burning Index	Fuel Moisture Percent	Wind Velocity Miles per Hour	Burning Index	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1	50+	2.0	1	9	10	10	29	3	9.3	3.0	25	9.0	3.5	30	30
2	1	50+	3.0	1	13	25	19	15	5	6.0	5.0	35	5.3	4.5	35	35
3	1	11.0	2.5	10			0	23	8	4.0	6.0	65	3.6	4.5	60	65
4	1	8.8	0	11			0	29	6	5.0	3.0	50	5.0	5.0	60	60
5	1	50+	0	1	85	45	65	2	2	11.8	7.0	8	10.2	5.5	9	9
6	1	11.7	6.0	7			0	5	3	8.0	8.0	20	8.2	6.5	20	20
7	1	10.0	2.5	7			0	13	8	4.0	4.0	40	4.0	2.0	30	40
8	1	12.2	0	4	T	T	0	18	5	6.0	2.0	25	5.6	3.0	35	35
9	1	13.0	1.5	6			0	26	8	4.8	4.0	55	4.3	3.0	50	55
10	1	14.2	0	4			0	34	8	4.1	3.5	65	4.5	3.0	60	65
11	1	10.0	3.0	25			0	44	10	3.5	3.5	80	3.8	2.5	70	80
12	1	9.7	1.5	25			0	50	6	5.0	2.5	65	4.9	2.0	60	65
13	1	16.2	2.0	9	10	10	10	40	0	50+	3.0	1	50+	2.0	1	9
14	1	50+	0	1	40	48	44	0	0	22.0	2.0	1	20.0	4.0	1	1
15	2	17.5	3.5	2			0	2	2	11.0	4.0	5	10.9	5.5	6	6
16	2	16.0	0	1	0	T	0	8	6	5.3	3.5	20	4.5	3.0	20	20
17	2	10.2	3.5	7			0	18	10	3.5	4.0	40	3.0	2.5	35	40
18	2	9.1	1.5	10			0	28	10	3.4	3.0	50	3.1	1.5	40	50
19	2	8.2	0	11			0	38	10	3.1	3.5	65	3.0	2.0	55	65
20	2	6.8	0	20			0	48	10	2.7	4.0	80	3.1	3.0	70	80
21	2	6.9	0	20			0	58	10	3.2	3.0	75	3.5	1.5	60	75
22	2	8.5	0	20			0	68	10	2.8	5.0	100	2.7	5.5	100	100
23	2	7.4	0	25			0	78	10	3.5	6.5	110	4.0	4.5	90	110
24	2	50+	0	1	152	150	151	0	0	50+	3.0	1	50+	0	1	1
25	3	50+	0	1	78	80	79	0	0	50+	0	1	50+	0	1	1
26	3	50+	0	1	14	11	12	0	0	50+	0	1	50+	0	1	1
27	3	50+	0	1	30	65	48	0	0	50+	2.0	1	50+	4.0	1	1
28	3	50+	0	1	30	40	35	0	0	45.0	3.5	1	29.0	2.0	1	1
29	3	15.2	2.0	1			0	3	3	8.1	4.0	6	7.9	2.5	5	6
30	3	13.0	2.5	2			0	11	8	4.3	3.5	20	3.9	3.0	20	20
31																

INSTRUCTIONS FOR RECORDING FIRE DANGER FACTORS AND PREPARING FIRE DANGER DAILY RECORD (Form 14-R-7, Rev. Jan. 1954)

GENERAL: The procedures discussed below are illustrated on the opposite page in the sample Fire Danger Daily Record, which is based on a report from a typical woods-type station, using meter 8-W. The report for open-type stations, using meter 8-0, is prepared in the same way.

Fuel Moisture Percent--columns 3, 11, and 14: Fuel moisture measurements should be recorded to the nearest one-tenth percent up to 20 percent; to nearest one-half percent above 20 percent. Example: nine and three-tenths percent should be recorded 9.3. If snow covers the ground in the woods at observation time (regardless of whether or not there is snow on the sticks), do not read the sticks. The letter S (for snow) should be recorded in the fuel moisture columns until the snow becomes patchy on the south slopes in the woods. Then resume reading the sticks.

Wind Velocity Miles Per Hour--columns 4, 12, and 15: Wind velocity measurements should be recorded to the nearest one-half mile, according to the wind correction table posted in the weighing shelter. Example: three and one-half miles per hour should be recorded 3.5. If anemometer cups do not turn during a 4-minute period at observation time, enter 0 (zero) in the wind velocity column. There is no need to read the wind when snow blankets the ground in the woods, because the burning index is automatically zero. A dash should therefore be recorded in the wind velocity column whenever the letter S (for snow) is recorded in the adjacent fuel moisture column.

24-Hour Rainfall--columns 6, 7, and 8: The amount of rain that has collected in your rain gage (since 2 p.m. yesterday) should be recorded in column 6, and the amount reported from a cooperating observer (if there is one) in column 7. Compute the average rainfall by adding the amounts in columns 6 and 7, divide by 2, and enter the average in column 8. When there is rain at your station, but no report is received from the cooperating station, enter a dash in column 7, and repeat your entry in column 8. When no rain occurs, zero should be recorded in column 8.

> NOTE that the rainfall amounts in columns 6, 7, and 8 should be recorded in whole units (without the decimal point). For example, one hundredth of an inch (.01") should be recorded as 1; 50 hundredths of an inch (.50") as 50; and 1 inch and 25 hundredths (1.25") as 125. If rainfall is less than one hundredth (.01"), enter "T" for trace.

Condition of the Lesser Vegetation--column 2: Record numeral 1, 2, 3, 4, or 5 as advised by your district forester or ranger. Do not attempt to make a classification change without the approval of the district officer in charge. The figure to use must be based on the estimated condition of the lesser vegetation, such as grasses, weeds, ferns, and shrubs in natural areas, regardless of whether your station is the open or woods type. It is emphasized that the amount or size of tree foliage, whether the hardwood trees are in full leaf or leafless, is not used as a criterion in estimating the condition of the lesser vegetation.

The following guide lines will be helpful in selecting the proper condition to record in column 2:

Use number 1 when the lesser vegetation is 90 percent or more cured. This is the normal winter condition that will usually prevail throughout most of the Northeast during the 5-1/2 month period from November 1 to April 15.

Use number 5 when the lesser vegetation is 90 percent or more green. This is the normal summer condition that will usually prevail throughout most of the Northeast during the 4-1/2 month period from May 15 to September 30.

Use number 2, 3, or 4 when the lesser vegetation is in the transition stage, neither fully cured nor green. In normal seasons these transition stages will usually prevail for periods of approximately 10 days each, from April 15-May 15 and from October 1-31. However, there is no assurance that any month in the year will be "normal," so watch out for the effects of unusual weather conditions.

In the spring, condition 2 may occur in late March in some years if a series of unseasonably warm days revives the lesser vegetation. Or the season may advance rapidly so that conditions 2, 3, and 4 apply only for short periods of less than a week each. A late spring freeze may set the conditions back from 4 to 3 or from 3 to 2.

In the summer, the thing to watch for in the normal green season is the effect of drought periods that will start curing of the lesser vegetation. Strict rules will not apply in every instance, but the Build-up Index may help in judging the condition. Vegetation condition 4 should be checked when Build-up Index reaches 40, condition 3 should be checked at 75, and condition 2 at 100. The lesser vegetation will very rarely proceed to condition 1 in the summer season. If adequate rains revive the lesser vegetation, the condition should be shifted back to 5 when warranted.

In the fall, with normal distribution of rainfall, the vegetation condition will usually remain in condition 5 until the first killing frost. If 50 percent of the vegetation is immediately killed, the shift would be made to condition 3, by-passing condition 4. A succession of hard freezes might produce condition 2 in a few days.

NOTE: The decision to change screens at open-type danger stations should not be confused with the condition of the lesser vegetation. The screens are shifted in relation to the amount of tree foliage, as described on pages 8 and 10, Technical Note 71, issued by the Southeastern Station.

Build-up Factor--column 10: The Build-up Factor is based on the 2 p.m. fuel moisture reading (column 11). Refer to the table on the central tab of the danger meter for the proper Build-up Factor, according to the measured fuel moisture. For example: if 2 p.m. fuel moisture is 6.2, enter 5 in column 10; if 2 p.m. fuel moisture is 28.5, enter 0 (zero) in column 10.

Build-up Index--column 9: This is the setting used on the danger meter in place of days since rain (type 5 meters). You will note that the Build-up Index disc is calibrated from 0 to 100. Therefore, do not enter in column 9 any values less than 0, nor more than 100. The Build-up Index is computed from data recorded in column 8 (rainfall) and column 10 (Build-up Factor). The procedure is simple: subtract the rain from the previous day's Build-up Index first, then add the Build-up Factor to obtain the new Build-up Index. In the absence of rain, simply add the Build-up Factor in column 10 to the previous day's Build-up Index. For example: Build-up Index yesterday was 20, rain 10 hundredths last night, and Build-up Factor today is 5. Today's Build-up Index would be computed as follows: 20 less 10 equals 10, plus 5 equals 15.

NOTE: The Build-up Index in column 9 is the meter setting used to derive both the 2 p.m. and 5 p.m. burning index of that day. The 9 a.m. burning index, or a recording at any other morning hour, should be based on the Build-up Index of the previous day.

For continuity of record, it is desirable when starting a new month to enter the status of the Build-up Index on the last day of the preceding month at the top of column 9.

Part Time Stations: Danger stations that operate only during the fire season, usually for a 2-month period in spring and fall, will have to estimate a Build-up Index in order to get started. If a

year-long key station is operating on the district, use the Build-up Index reported from the key station as a starting point, and thereafter proceed on your own measurements. If there is no key station operating, an estimate of the Build-up Index should be made on a basis of elapsed time since rain. Count back the days to the last rain of 50 or more (1/2 inch or more) and multiply the number of days by 3. For example, 6 days times 3 equals 18--the estimated Build-up Index on your opening day.

BUILD-UP INDEX AS A GUIDE TO WOODS CLOSURES

The fuel moisture sticks indicate the moisture condition of the surface layer of litter. The Build-up Index reflects the cumulative build-up of inflammable conditions in the litter below the surface layer. Hence, fires that occur when the Build-up Index is high and when lower fuels are drying out, are likely to be deeper-burning fires that will be harder to control and will require more mop-up and patrol. Since the Build-up Index will be computed daily at each danger station, the trend toward a potentially dangerous fire situation can be recognized in advance from these daily reports.

There is no single critical point on the Build-up Index scale, but values above 30 should be viewed as a warning signal that a build-up above normal is developing. To illustrate, on an annual basis, from records for the 3-year period 1950-52, less than 10 percent of the days on the Monongahela National Forest were above 30. On the other end of the scale, a Build-up Index of 80 is definitely in the danger zone. New England forests are usually closed well in advance of the 80 point. For example, the 6 closures effected in Rhode Island, 1950-52, averaged a Build-up Index of 52. Consequently, a Build-up Index range of 30 to 60 is recommended at present as a guide to the State Foresters in requesting woods closures from their governors. Closures in the lower section of this range (30 to 40) will probably be needed only when unusually high winds have prevailed, or are predicted, or when an exceptional risk is expected, such as the opening of hunting season.

In areas where a full closure calling for a governor's proclamation does not seem warranted, or in units where closure laws are not in effect, the Build-up Index should be a useful guide in stepping up prevention efforts to alert the public as the build-up progresses.

In application, the Build-up Index should be computed by districts or closure zones, as was done with the cumulative danger index, by computing an arithmetic average of the daily Build-up Index reports from the danger stations representing the unit. The Build-up Index is simpler and more accurate than the cumulative danger index; hence, the

special computations involving the use of normals and adjustments for precipitation may be discontinued.

There will perhaps be some question as to how widely the type 8 meter can be applied outside of Region 7. According to the Division of Fire Research at the Southeastern Forest Experiment Station, Asheville, N. C., preliminary tests made by them indicate that type 8 meter can be used with satisfactory results for the mountainous areas of Region 8. Whether it will apply equally well elsewhere remains to be determined.

Annual Report 1953

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EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. Department of Agriculture - Forest Service

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ANNUAL REPORT 1953

SOUTHEASTERN FOREST EXPERIMENT STATION

INTRODUCTION

Once again it is time for an Annual Report. What has the Station been doing in forest and range research during the past year? This booklet gives some of the highlights.

As a result of reorganizations in the Department of Agriculture, the Asheville Division of Forest Disease Investigations headed by George Hepting, which formerly operated under the Bureau of Plant Industry, Soils and Agricultural Engineering, was transferred at the end of 1953 to the Forest Service and is now an integral part of the Southeastern Station. The same holds true of the Asheville Division of Forest Insect Investigations headed by Charles F. Speers, formerly under the Bureau of Entomology and Plant Quarantine. In the past, Hepting and Speers and their men have cooperated with us so closely they were considered as part of the Station family. We now welcome them as full-fledged members and anticipate no dislocation of their work or their relations with the public.

An important trend in 1953 was greater emphasis on research in regeneration and genetics. This is in response to the tremendous increase in forest planting today and to the rising demand for better trees in the future. If all goes well, more than 400 million seedlings will be set out in the South in 1954; and naturally there is more insistence as time goes on that these seedlings should be the best obtainable. The Station made notable progress in this direction in 1953 as well as stimulated genetics research in other places. Fortunately, the Station has a start of more than 10 years based on its naval stores genetics work at Lake City. The State of Florida has sensed the importance of this research by allocating $20,000 a year for 2 years to the Station to speed up our genetics, regeneration, and silvicultural research. The Ida Cason Callaway Foundation, of Hamilton, Georgia, is also providing valuable assistance.

Thanks to substantial cooperation from four agencies named on page 5, long-needed research in Sandhill regeneration has been stepped up.

Our South Florida project, with headquarters now at Fort Myers, has been able to increase the size and scope of its research work because of a grant of $10,000 a year for 2 years from the Florida State Legislature, in

addition to aid from the Atlantic Land and Improvement Company and the Collier Company. The problem there is to help put millions of idle or semi-idle acres to work and to figure out the best integration of forestry and forest grazing in the wide subtropical spaces just north of the Everglades.

The survey of forest resources in Georgia was completed in 1953 and one unit in North Carolina also finished. Several important forest grazing studies have been reported on in substantial bulletins. The motion picture "Waters of Coweeta," illustrating watershed management research in the Southern Appalachian Region has won distinction abroad and is in constant demand at home. Thousands of requests for information--more every year--pour in, and the Station issued over a hundred publications in 1953. All in all, it has been a productive year.

FOREST MANAGEMENT

From the Tidewater Research Center in Virginia to the Lake City Research Center in Florida, the field branches of the Station conduct practically all of its research in forest management. The Station attempts to see that this work is geared to the needs of local people, and that it is also properly coordinated for highest efficiency.

To keep its research center programs on the track of the major problems, the Station relies heavily on advisory committees for each of the seven research centers. These committees analyze trends in forestry currently and suggest the direction which future research should take.

Notable new developments in addition to the upsurge in planting and genetics are the use of improved machinery and chemicals in the culture of the forest, the increasing application of forest cropping practice to even poor forest lands and secondary forest types, and the increasing demand for knowledge of the management of good southern hardwoods. All of these trends enliven the researchers' race with time to find out how to grow the largest quantity of the best timber crops on the land area available.

REGENERATION

Continued high production of the pine industries in the Southeast depends on future supplies of pine timber. Unfortunately, much of the land from which the required pine trees are cut is left without sufficient seedlings or seed supply to maintain a productive pine forest. A resurvey of about 60 percent of the Station's territory (chiefly in the southern portion) indicates that hardwood types now dominate 29 percent of the area compared with 17 percent about 15 years ago. Planting is one solution to the maintenance of pine, but in many instances natural

regeneration can be obtained if proper techniques are applied--often at small cost. In either case it is most important that we develop our knowledge to the point where successful regeneration can be assured. The Station's program includes regeneration studies for the major southern pines and also for some important minor species. Some progress is also being made on the problem of regenerating desirable hardwood species in view of their special importance to a number of primary and secondary forest industries.

Timing of Release Important in Cone Crop Stimulation

Timing of the cut has an important bearing on the amount of seed available for natural regeneration. Cutting in good seed years or immediately after the annual peak in seedfall usually assists regeneration. But now that we know seed production can be increased by release of seed trees in advance of cutting, time assumes even greater significance.

Last year's report of the Station explains that seed production of loblolly pine could be increased very significantly by crown release of the seed trees several years in advance of logging. Further information, portrayed in figure 1, shows that the timing of the release cutting determines whether the stimulated crop will be the third or fourth annual cone crop after cutting. In southeastern Virginia, for example, it is safe to count on an increase in the third succeeding cone crop if the trees are released before the end of May. Released trees continue to produce larger crops for at least 2 more years. There is therefore at least 3 years' leeway in the time when a fresh seedbed, created by logging, can be made to coincide with larger amounts of seeds.

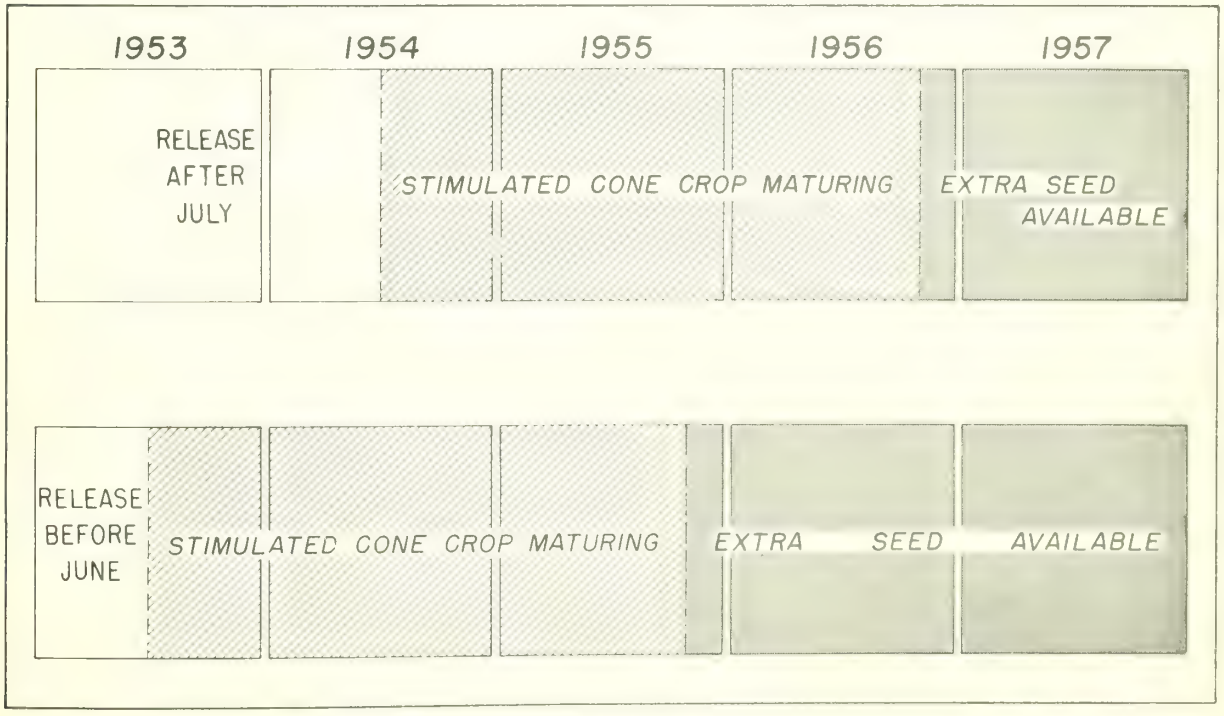

Figure 1.--Release before June, as compared with release after July, brings a stimulated seed crop one year earlier.

Correction Factor for Cone Crop Estimates

In loblolly pine, cone crop estimates can be made a year before the cones are due to ripen by counting conelets on sample trees cut on nearby logging operations. Initially, it was supposed that the cone crop could be estimated from the ratio of number of immature conelets to number of mature cones. Experimental forecasts made during the past 3 years in North Carolina and Virginia show that conelet count should be reduced by 45 percent in order to obtain a closer estimate of the future crop. This factor is needed to account for average losses of conelets before they mature.

First-Year Survival of Different Species Planted on Bottomlands

The increasing shortage of high-quality hardwood timber for the furniture and other industries in the Southeast has recently focussed attention on bottomland hardwoods. A large share of the bottomland areas is now in such condition that seeding or planting may be required to rehabilitate them. But knowledge concerning the artificial regeneration of hardwood bottoms is extremely limited. To increase information, a planting study was initiated in the South Carolina Coastal Plain during the winter of 1952-53. Six species were tested by planting 1-0 nursery-grown stock from local seed sources in fenced plots to exclude livestock. In addition, two species of oak were direct seeded. Results from the first installations are shown in table 1.

Table 1.--Survival after 1 year of various tree species planted or seeded on two bottomland hardwood sites on the Santee Experimental Forest, South Carolina

Species	Sites			
	First bottoms		Terraces	
	Cleared	Not cleared	Cleared	Not cleared
	Percent	Percent	Percent	Percent
Planted				
Yellow-poplar	21	21	84	99
Shumard oak	52	70	76	86
Cherrybark oak	64	76	76	77
Cow oak	74	79	86	84
Redcedar	26	32	81	92
Loblolly pine	78	81	94	90
All planting stock	50	58	82	88
Direct seeded				
Cherrybark oak	47	21	36	30
Shumard oak	30	37	78	31

Although not conclusive, these first-year results are at least indicative of some of the planting possibilities on bottomland hardwood sites. High water, particularly one flood before the growing season, caused most of the mortality in the first bottoms. All species did well on terrace sites, with yellow-poplar and loblolly pine outstanding. Somewhat better survival resulted on uncleared plots, indicating a temporary beneficial effect of cover during periods of drought. Rodents accounted for much of the loss in the acorn sowings, which had no screening or other protection.

Regeneration of South Florida Slash Pine

A unique problem in regeneration is provided by the 1,750,000 acres of south Florida slash pine (Pinus elliottii var. densa) in the subtropical portion of Florida. Over half of this area is denuded and will require artificial reforestation, but the results of past planting of south Florida slash pine have been unsatisfactory. Research on this problem was started by the Station in 1951, in cooperation with the Atlantic Land and Improvement Company, the Collier Company, and the Florida Forest Service.

Preliminary results show that seed losses are caused by cotton rats on the dry palmetto sites and by birds on the wet prairie sites, that nursery fertilization and lifting practice both have a noticeable effect on the survival of planted seedlings, and that the important problem in planting is to bring the seedlings through the first 5 or 6 months after winter planting. This is the critical drought period in the subtropical rainfall pattern of south Florida.

Planting and Seeding Studies Started in Sandhills

With an increasing scarcity of good pine land for purchase, the ownership of land for forest production is rapidly spreading to include anything which may produce timber. One of the largest remaining acreages of cheap land is to be found in the Sandhills or deep sands of the Coastal Plain. The big problem here is to convert extensive acreages of valueless scrub oak to pine. Research in Sandhill regeneration, previously very inadequate, is now getting under way in cooperation with the South Carolina State Forestry Commission, the Savannah River Project (Atomic Energy Commission), North Carolina State College, and the Division of Forestry of the North Carolina Department of Conservation and Development.

One of the new studies compared survival of planted longleaf pine by seedling grade, with and without needle clipping, by season of planting in major soil groups. The results have more than usual significance on account of an extremely dry and hot early growing season. Clipping of needles to approximately 5 inches improved survival of Grade 1 stock planted in January, but the treatment had no apparent effect on Grade 2 seedlings planted in January, or seedlings of either grade planted in March. Regardless of season, treatment, or seedling grade, planting on sandy loam was more successful than in the deep sands.

Longleaf direct seeding tests in the Sandhills show little promise of success so far. Unprotected sowings on the Savannah River Project area showed an 85 to 95-percent loss to rodents and birds. Protection with conical

screens excluded birds, but up to one-half the seed was lost to rodents, even though the screens were pinned down with wire. A serious white grub problem encountered in the Savannah River plantations is discussed in the Forest Insect section page 52.

Regeneration Techniques for Sand Pine

Sand pine (*Pinus clausa*), a minor pine species, attains considerable local importance in Florida. On the Ocala National Forest alone, there are 210,000 acres of sand pine, comprising about 60 percent of the forest land. Sustained yield management on the Forest has been obstructed by the extreme difficulty of obtaining reproduction after cutting. Existing stands are largely the result of accidental fires followed by favorable temperature and moisture conditions. Cooperative investigations with the Ocala National Forest have been carried to the point where it is now possible to make at least interim recommendations for regenerating sand pine at the time of the harvest cut.

Sand pine stands which are cut over from July through December, and are tractor logged and skidded, should need no further treatment. Tracts which are cut over during this same July-December period, but are not tractor logged and skidded, should be scarified with a disk or brush-cutter about 1 to 2 months after cutting. Stands which are harvested in the January-June period should be scarified whenever the majority of the cones on the fallen tops open, but not later than December. Areas which fail to show satisfactory stocking 5 years after cutting should be interplanted with 1-1/2-year-old sand pine seedlings. November and December are the best planting months.

STAND IMPROVEMENT

Hardwood Competition Develops in 3 Years After Logging

The significance of early competition from low shrubs and hardwoods in the establishment of loblolly pine is well indicated from results of a study carried out in the Tidewater section of Virginia. This shows a rapid rate of increase of hardwood cover during the first 3 years after logging, followed by a marked slowing down thereafter. This suggests that the composition of the future stand is well established in 3 years. Therefore, the stocking of free seedlings at that time should be closely related to the eventual stocking of dominant loblolly pine, barring further cultural work.

Predicting Growth From Pine Seedling Characteristics

As an aid in determining the need for release of pine from competing vegetation, it was found that certain seedling measurements were an excellent clue to future height growth. Seven hundred 2- and 4-year-old loblolly seedlings measured in a North Carolina study revealed that (1) the ratio of height to diameter, (2) terminal bud length, (3) needle length, or (4) number of branches in descending order could be closely correlated with future height growth. For practical use it appears that number of branches will be the simplest to apply.

A related study of loblolly pine regeneration in shelterwood stands in the Georgia Piedmont showed that seedling growth and form quotient are closely related to stand density and shade level (fig. 2).

Estimating Area Shaded by Competing Hardwoods

Cultural measures to release pine seedlings are becoming so common that more precise estimates of the expected benefits are needed. The need for liberating pine seedlings, as well as the expected benefits from poisoning or girdling, can be judged quite accurately from the potential pine-growing area under the crowns of inferior species. A method of estimating the percent of area shaded by hardwoods 4 inches in diameter and larger has been developed from a study of residual hardwoods on cutover loblolly pine-hardwood tracts near Franklin, Va. Knowing the basal area of hardwoods per acre, an estimate of percent of area shaded can be obtained by multiplying basal area by 1.4. This is the area which a successful girdling or poisoning job would make available for pine.

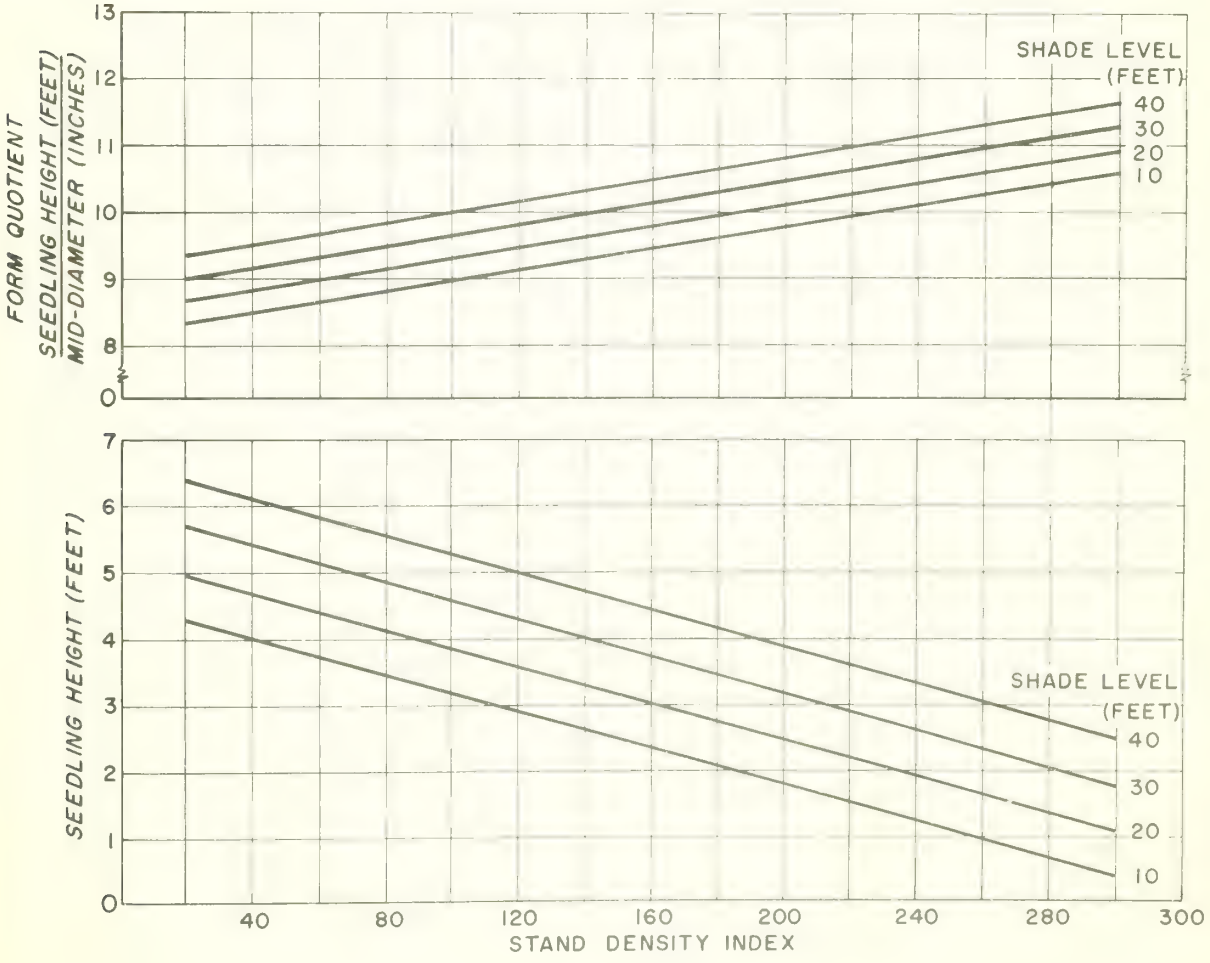

Figure 2.--Height and form quotient of 6-year-old pine seedlings under different pine overwood densities and levels of shade.

Recovery of seedlings liberated from larger competing stems is usually quite rapid (fig. 3). Even those which have been suppressed for long periods quickly build normal crowns and begin rapid height growth.

Estimating Man-Hours to Apply Ammate in Notches

Various methods of controlling inferior species retarding the establishment and growth of pine have been developed in the past several years. An important consideration is the time required to do such a job. Using a 3-man crew consisting of two axe men and one man to apply Ammate

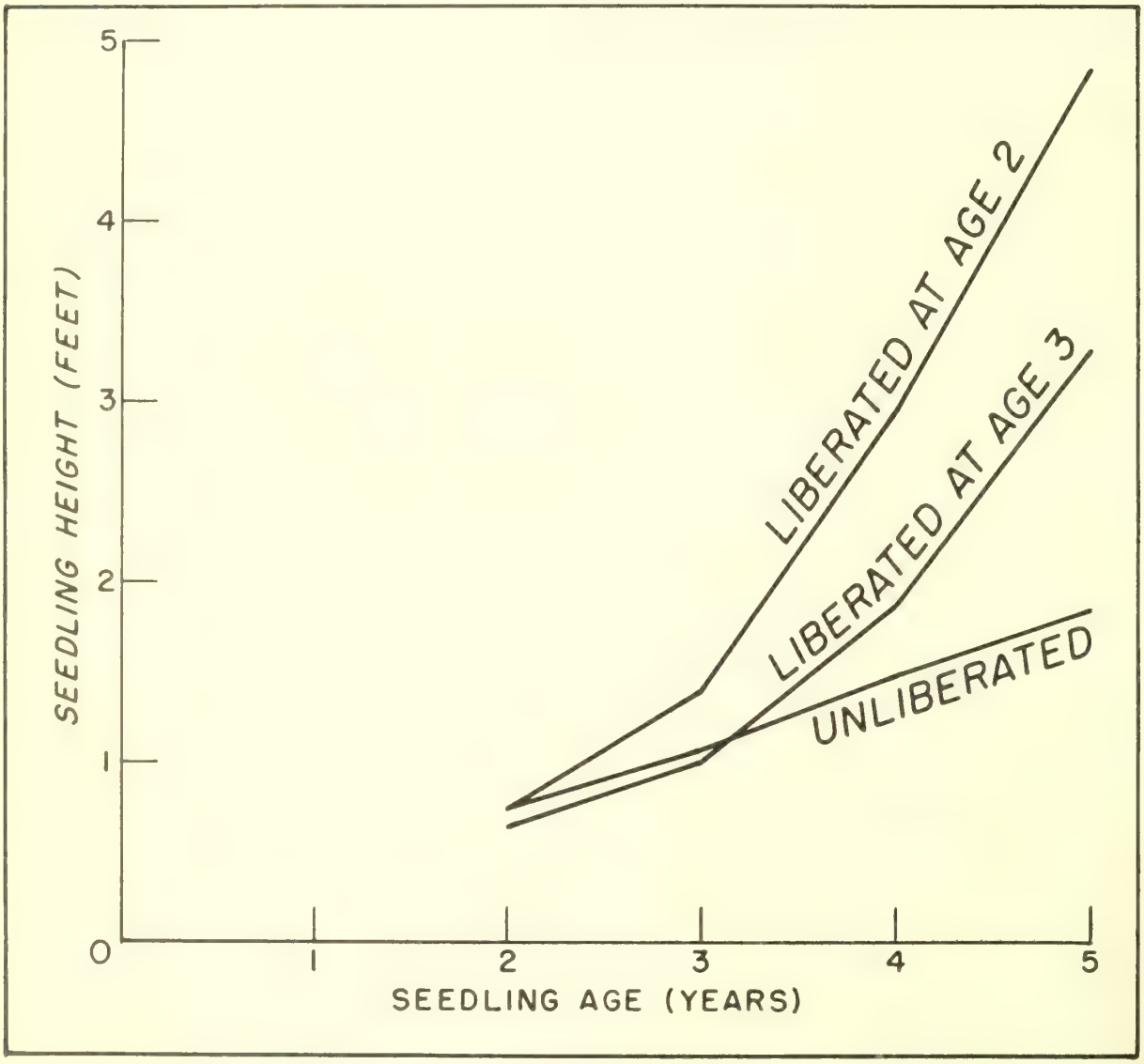

Figure 3.--Heights of loblolly pine seedlings 2 to 5 years old in the Bigwoods Experimental Forest with and without liberation from overstory hardwoods 4 inches and larger.

(ammonium sulfamate) in notches, the following equation was found to provide an accurate estimate of time required to treat pine-hardwood stands where the stems to be treated are mostly under 6 inches d.b.h.:

Man-hours per acre = 0.009(sum of the diameters)-0.005(number of stems)

This method of controlling inferior species requires about four pounds of ammate per 100 inches of diameter treated.

Poisoning With the Cornell Tool

Where low competition is a problem, there is need for an efficient but economical method of controlling small stems up to 3 inches in diameter which overtop pine. A promising treatment involves the use of the Cornell poisoning tool to apply Ammate in solution at the rate of 6 pounds to each gallon of water. The method of application is by incision or jabs around the basal perimeter--one jab per inch of diameter. In an experiment installed in January 1952 in coastal South Carolina 76 percent of the trees were killed or nearly killed within 1 year, resulting in effective release of seedling and sapling pine from competing gums, oaks, and myrtles.

Honeysuckle, an increasingly serious problem in the Piedmont, resists control. Preliminary tests on the Hitchiti Experimental Forest in Georgia involving 10 to 80 pounds of C.M.U. (chlorinated methyl urea) per acre, gave quick foliage kill but poor control of roots, particularly at lower rates of application.

FOREST GENETICS

The production of more and better forest products on the available land is the chief goal of forest management research in the Southeast. In the main, this involves the development of better cultural practices. But to get the most out of the land we also need better trees--superior strains of trees having improved growth rates, greater resistance to disease, better form, and higher quality. This job requires fundamental research, an intensive search for superior strains of trees, cross-pollination among superior individuals, and an extensive program of progeny testing.

The Station's genetics research was started at Lake City, Florida, in 1941. The genetics work as well as the other forest management research at Lake City was speeded up during 1953 by an appropriation of $20,000 from the State of Florida. Cooperation of the Station with the Ida Cason Callaway Foundation genetics project in Georgia was intensified, and several research centers initiated small genetics studies during the year.

Mature Cones Collected From Rooted Slash Pine Cuttings

Recently, at Lake City the project to develop high-yielding pine for gum naval stores made an important step ahead when mature cones were collected from 7-year-old rooted slash pine cuttings. This is the first recorded production of cones on slash pine cuttings. The initial milestone in this project was the rooting of cuttings from superior, mature trees in 1943-44, a feat never before accomplished. The largest planted cutting, now over 25 feet tall, is facetiously known at Lake City as "the most photographed tree in the world."

Figure 4.--Aerial roots on a slash pine branch after special treatment with a growth hormone. The treated area was wrapped in wet moss and covered with plastic for several weeks as shown on the twig at the left. This technique, called "air-layering," will facilitate the propagation of cuttings from "elite" trees.

Air-layering a Promising Technique for Slash Pine Rooting

It is a well established fact that propagation by vegetative means, such as rooting branch cuttings, assures progeny of the same characteristics as the parent. In an effort to develop more efficient propagation techniques for slash pine, intensive studies are under way at Olustee and Gainesville, Florida. Air-layering, an established technique in horticulture, has now been used with 85-percent success on slash pines 5 to 17 years old. The technique involves girdling a twig, painting the wound with a chemical growth substance, and binding wet moss about the wound with a plastic sheet that has been treated with nutrients and a fungicide. When roots appear (fig. 4), the twig is severed from the tree and planted in a nursery bed for further development.

Grafting Techniques for Slash Pine

Intensive studies have been conducted at Lake City to develop improved vegetative propagation techniques for slash pine for use in the genetics project. As shown in the following table, the bottle graft method gave 75-percent success in the greenhouse and 95-percent success in the field, where scions were grafted to natural seedlings under the partial shade of a pine stand.

Table 2.--Proportion of successful graft unions of slash pine in relation to grafting method and environment

(In percent)

Grafting method	In greenhouse		In pine stand	
	No cover	In sweatbox	No cover	In humidity chamber
Cleft	20	30	0	5
Veneer	30	55	0	45
Bottle	75	25	95	55

Inasmuch as the bottle method supplies water to the base of the scion from a small container, this method requires no humidity chamber. With veneer and cleft grafts, a humidity chamber is beneficial because it reduces the drying out of the graft union caused by transpiration drain on the scion.

Grafting of one species on another has been used as a shock treatment to induce early flowering of trees and thereby save years between generations in tree-breeding research. Such heteroplastic grafts have been made successfully at Lake City with scions of slash pine on stocks of loblolly, ponderosa, pitch, and white pines, Douglas-fir, Norway spruce, and white spruce. It is too soon to tell whether early seed production will follow.

Superior Trees Producing Superior Offspring

The cooperative tree improvement program with the Callaway Foundation, established in 1950 in the Georgia Piedmont, now has 30 acres of outplantings for testing longleaf, slash, shortleaf, and loblolly pine progeny from wind-pollinated superior mother trees. Distinct differences in height growth are apparent. For example, the seedlings from one parent tree of loblolly pine averaged more than twice as tall as the seedlings from another loblolly pine at 1 year of age.

The first seedlings from controlled-pollination of superior loblolly and slash pine phenotypes were produced in 1953. In each of three groups (two loblolly x loblolly and one loblolly x slash) control-pollinated

year-old seedlings averaged taller than the more vigorous wind-pollinated group from either parent.

Good Results With Hybrid Poplar

A small test of hybrid poplars at the Coweeta and Toccoa Experimental Forests indicates that on good sites in the Southern Appalachians the hybrids show better growth than outstanding native species. Best results came from a hybrid clone designated Androscoggin (Populus maximowiczii x P. berolinenis). In 13 years, survival averaged 76 percent, height 46 feet, and diameter 4.7 inches.

Station Cooperating in Seed-Source Study

Several of the 50 plantations in the large cooperative seed-source study of the Committee on Southern Forest Tree Improvement were established by the Station's research centers. One at Lake City on land made available for genetics studies by the National Container Corporation reveals that seedlings from the southernmost seed origin of slash pine (Polk County, Florida) grow appreciably slower than seedlings from more northerly origins. These seedlings may be hybrids between north and south Florida slash pines.

Supplemental local seed source studies have been started, one in the south Georgia-north Florida area testing slash pine, and another in South Carolina for longleaf pine.

Introduced Species in Appalachian Mountains

Existing plantations containing introduced species often yield information regarding the adaptability of the species to a given area. One group of such plantations is at the Bent Creek Experimental Forest. Currently 32 species are involved, but only 10 species approach Southern Appalachian mountain native species in vigor and growth. Of these, only three show promise for further planting. Atlantic white-cedar grew well on a wet site, but was very susceptible to root and butt rot. Loblolly and pond pine were superior to all others in growth rate to date, even though they may not be climatically adapted to the area. Growth rates of the species tested are given in Station Paper 27.

PRUNING

Bud Pruning of Slash and Loblolly Pine

Bud pruning is a special technique requiring annual removal of all lateral buds or new branchlets. At the Hitchiti Experimental Forest in a test with slash pine, seven prunings have resulted in a significant reduction in height and diameter growth. This amounts to about 3-1/2 feet in height (in 6 years) and 0.25 inch in diameter (in 4 years). The seven annual prunings have now cleared one 16-foot log on 87 percent of the trees. Total time for each bud pruning to date amounted to 6 to 8 minutes per tree.

In loblolly there is also a reduction in growth from bud pruning. More serious than this is the occurrence of epicormic sprouting. About 95 percent of the pruned trees average about five sprouts per tree, a factor which increases pruning time and prevents development of a clear stem.

Longleaf Pine

Comparatively little effort has been devoted to the problem of thinning for optimum stand density in the longleaf stands of the Southeast. A recently summarized study involving 22 quarter-acre plots established in 1932 in Florida is indicative of some of the basic relationships between stand density and growth rate per acre and per tree. The results obtained show that maximum volume production of flatwoods longleaf pine is possible over a wide range of stand densities, but that diameter growth and crown development is distinctly favored by light density. The data further show that where fairly wide spacing is used, such as to favor gum yields and forage production, the sacrifice of wood volume production of longleaf pine on poor flatwoods sites may be less than is generally supposed. Also, in view of an early expression of dominance which characterizes the species, precommercial thinnings do not appear to be justified.

White Pine

Were it not for the pioneering efforts in forestry on the Biltmore Estate, information on the management of Appalachian white pine plantations would be several decades in the future. Results are now available showing the effect of six thinnings (1916 to 1953) in a white pine plantation 53 years after planting, or 56 years from seed (fig. 5). Plot studies show

Figure 5.--Eroded hillside where pines were planted in 1899, and stand 48 years later.

that management in the form of these six intermediate cuttings has increased the total yield of the stand by $200 per acre in terms of stumpage value (fig. 6). Furthermore, nearly one-third of the total wood yield to date on the thinned area was obtained from the intermediate cuttings, which removed largely trees that will die without management (fig. 7). Sawtimber yields are 50 percent greater as a result of the thinning, and cubic-foot yields are 35 percent greater.

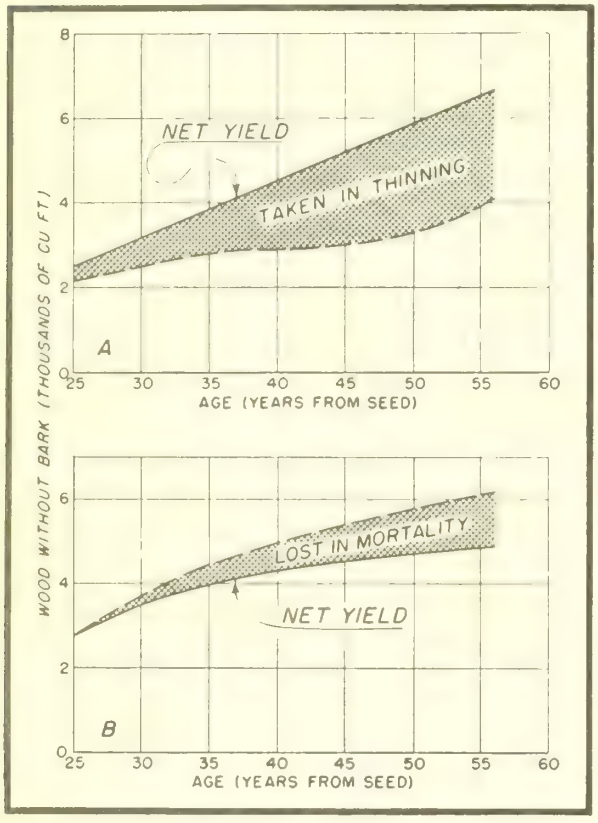

Figure 6.--Per-acre wood production in both saw logs and pulpwood as related to age. A thinned stand, and B unthinned.

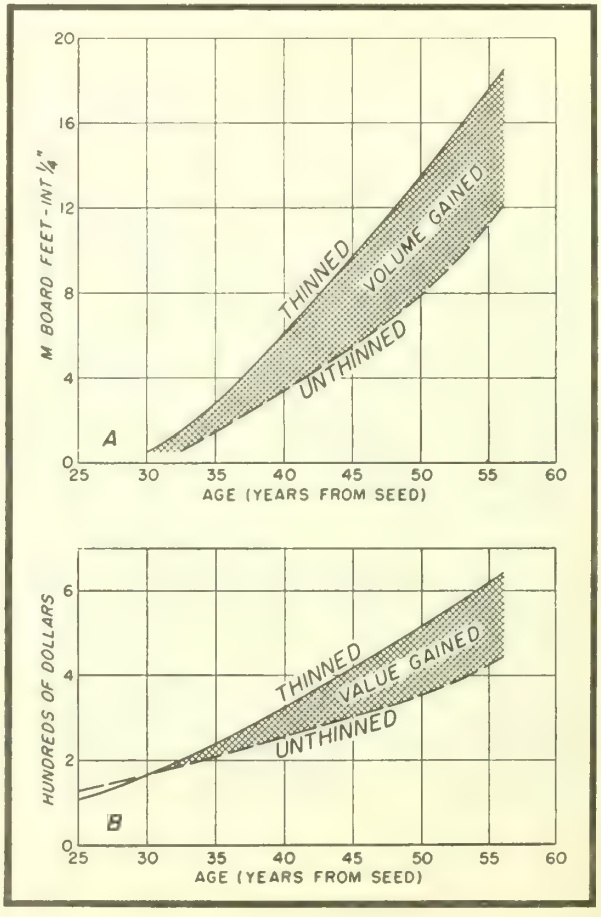

Figure 7.--A shows per-acre production in volume of saw logs only, and B shows value of both saw logs and pulpwood.

CUTTING METHODS

Methods of Cutting in Pine Pulpwood Stands

Loblolly pine pulpwood stands are usually ready for their first commercial cut at 25 to 30 years of age. Many are cut with no regard for their future potentialities; others are cut under a definite plan of management. A study of the economic and silvicultural aspects of six different methods of cutting was initiated in 1939 on five parallel sets of plots in Virginia and the Carolinas. A comparative analysis between methods was made 9 years later. Cutting methods used and the financial comparisons among them are shown in table 3.

Table 3.--Financial comparisons for a 9-year period after application of six methods of cutting in young loblolly pine stands

(Dollars per acre)

Method of cutting	Pulpwood value 1939 [1]		Stand value 9 years later [1]		Expectation value 1939 [2]	
	Cut	Left	As pulpwood	As saw-timber & pulpwood	As pulpwood	As saw-timber & pulpwood
4 seed trees	96	5	13	33	106	121
12 seed trees	92	9	22	60	109	138
Shelterwood (40 trees)	77	27	48	159	114	199
7-in. diameter limit	79	24	33	33	104	104
Moderate thinning from below	42	56	93	196	113	192
Heavy thinning from below	54	51	82	231	117	231

1/ Pulpwood stumpage $4.00 per standard rough cord. Sawtimber stumpage $30 per M bd. ft. (Int. 1/4-inch rule).

2/ "Expectation value 1939" is value of volume removed in 1939 plus value of residual stand 9 years later discounted at 3 percent.

The heavy thinning made the best financial showing on the basis of expectation value 1939. The average stand in this treatment group had a value of 105 dollars for pulpwood at 25 to 30 years of age. Half of this stand, left after thinning, increased to a value of $231 for sawtimber and pulpwood 9 years later. One of the heavily thinned stands is shown in figure 8.

Another major finding of the study was the failure of the seed-tree and other harvest cutting methods to regenerate the young stands that were cut at 25 to 30 years of age. Even 12 seed trees, the most successful of

BEFORE CUTTING

AFTER CUTTING

9 YEARS AFTER CUTTING

Figure 8.--A 27-year-old pine stand given a heavy thinning where all merchantable trees except 100 of the best dominants and codominants per acre were cut. Trees with number and band represent residual stand. This method of cutting produced the best volume growth and gross returns. Plot located near Jarratt, Va.

the methods tried, resulted in an average of only 360 pine seedlings per acre 3 years after the harvest. This study illustrates the difficulties to be expected when young loblolly pine stands are harvested before the trees are sufficiently well developed to provide adequate seed, and when no cultural measures are used to prepare a seedbed or control hardwood competition.

Clear Cutting Raises Water Level in Flatwoods

Of considerable concern to research workers in the lower Coastal Plain are the problems associated with too much water on or near the surface. This excess water may be a chief cause of poor stocking in established pine stands or may explain why certain sites are taken over by less valuable species. Many people have speculated that removal of timber on low, wet sites reduces the transpiration draft and thus allows the water table to rise. A recent study in tidewater Virginia indicates that this is true. A series of ground water wells were installed on a straight line extending from the center of one clear-cut strip into other uncut, clear-cut, and selectively cut strips (fig. 9). This level area was once covered by a heavy stand of pine and hardwood timber growing on Bladen silt loam.

Under the selection stand the water table was at a lower level during the growing season than in the adjacent clear-cut strip. The same effect of a timbered stand was recorded under an uncut strip of timber. At 1/2-chain distance away from either timbered stand the water table was

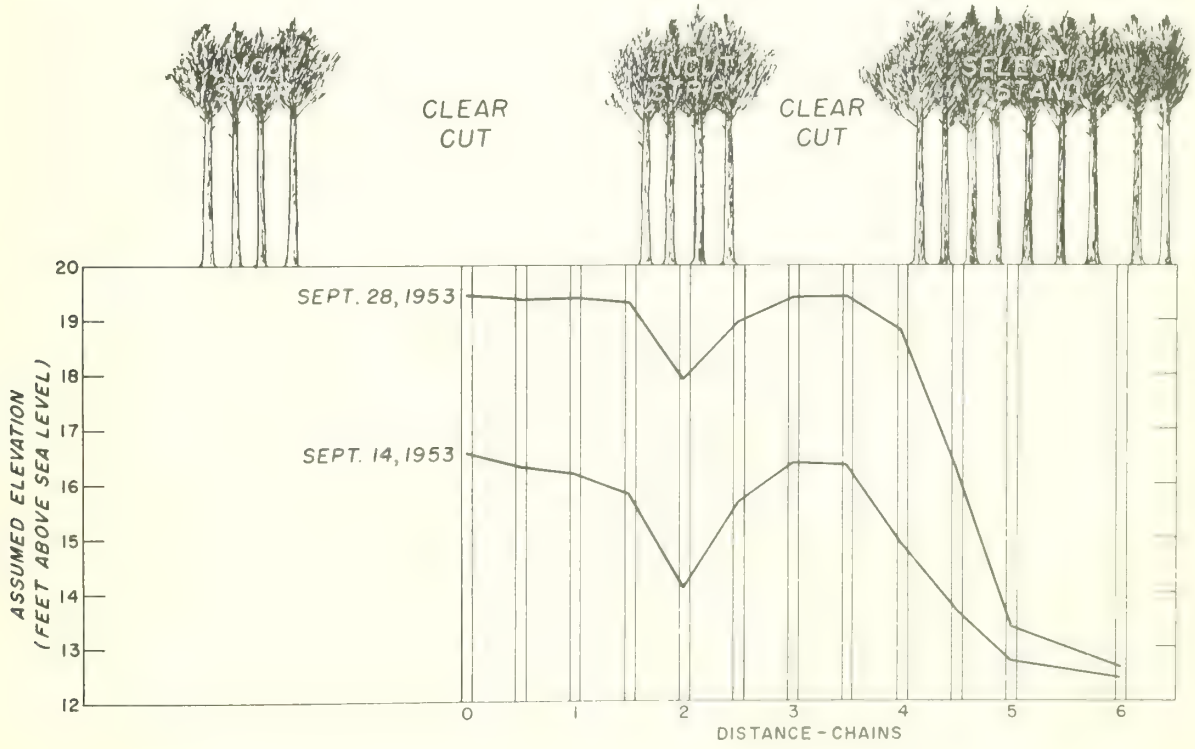

Figure 9.--Typical water-table profiles through different types of stands on the Bigwoods Experimental Forest.

at a uniform high level. During the period September 14 to September 28, 3.21 inches of rain raised the water table about three feet in the clear-cut area and an insignificant amount 2 chains within the selection forest.

FINANCIAL ASPECTS

Mountain Logging Costs

Factors affecting the cost of logging mountain hardwoods were the subject of an intensive investigation made at some 30 different logging operations within a 75-mile radius of Asheville, N. C. The results of this study appeared recently in Station Paper No. 32, "Logging Methods and Costs in the Southern Appalachians," by Robert A. Campbell. Some of the report's highlights are: (1) Log making--power saws will do the job at half the cost of hand sawing. Most efficient use of power saws requires that delay time be kept low and saw performance high. (2) Skidding--medium tractors (D5 and TD9) are consistently the cheapest motive power for all distances and load sizes; teams are second best. Light tractors (D2 and TD6) are not very practical in mountain logging. Regardless of equipment used, capacity loads should be skidded whenever possible. (3) Loading--power loading is more efficient than hand loading only in situations where there are no bank-loading spots or when logs are both skidded and loaded by the same machine. (4) General--Intelligent supervision, proper size of crew, and advance work planning will make logging both easier and safer for the worker and produce substantial savings for the operator. Total logging cost per M board feet is inversely related to tree size; it is nearly twice as high for 12-inch trees as for 24-inch trees.

Board Widths Obtainable From Pine Trees of Different Diameters

Timber buyers and appraisers, particularly those in pine "roofer" areas, might gage the value of a tract of timber more accurately if they had an estimate of the percentages of various board widths which might be produced from a particular stand.

In 1935 Telford and McMillan determined the board widths which could be cut from loblolly and shortleaf pine trees of different diameters. Studies made at 10 separate operations by the Hitchiti Research Center showed that the estimates are still applicable. Board-width yields obtained from representative stands of different average diameters are given in table 4.

Effect of Utilization on Topwood Volume

Many sawtimber stands are cruised and sold on the basis of an 8-inch merchantable top. But often the operator will cut to a 6-inch top or beyond, particularly on the smaller trees. He gets an unpaid-for volume in small, knotty logs, but on the other hand, the seller may be cut out of a possible topwood sale for pulpwood. Inspection of table 5, developed in a cooperative study with the Westvaco Experimental Forest, in South Carolina, shows that in cutting to a 6-inch rather than 8-inch top, the potential pulpwood volume in the smaller trees may be reduced by about 80 percent.

Table 4.--Actual versus estimated board widths obtained in a pine roofer operation in stands of different average tree diameter

(In percent of total)

Average d.b.h. of stand (Inches)	Volume cut	Basis	Board width (1-inch thickness)				
			4 & 5 inches	6 inches	8 inches	10 inches	12 inches
	M bd.ft.						
12.4	233	Actual	26	46	26	2	--
		Estimated	27	45	22	5	1
13.3	49	Actual	25	35	24	16	--
		Estimated	19	37	25	13	6
14.8	68	Actual	15	32	42	11	--
		Estimated	15	33	34	16	2
16.5	27	Actual	18	20	25	21	16
		Estimated	14	22	25	25	14
17.9	7	Actual	11	22	30	13	24
		Estimated	7	20	24	27	22

As a further aid in estimating yield of pulpwood from tops, topwood volume tables prepared from data collected in Dooley County, Ga., have been prepared for slash and longleaf pine. They are published in Station Research Note 42.

Log Grades and Lumber Grade Recovery for Southern Pine

A system of grading southern pine logs has developed from a cooperative project by the Southern and Southeastern Forest Experiment Stations, the Forest Products Laboratory, and the Southern Region of the U. S. Forest Service. This log-grading system--described in the report, "Interim Log Grades for Southern Pine," published by the Southern Forest Experiment Station in 1953--provides a means of estimating the quality of logs in terms of yard lumber grade recovery or dollar value per thousand board-feet. The new grading system is simpler than those used earlier and stratifies the logs into value groups more accurately. A series of lumber-grade yield studies for the various species and timber types of southern pine will do much to increase the value and use of these log grades.

Grade yields have been analyzed for the logs which were used in developing the new log-grading system. The percentage of lumber-grade yield by log grade at each of two locations is shown in table 6.

Table 5.--Topwood volumes per M board feet of sawtimber[1/] (Int'l. 1/4-inch rule)

D.i.b. utilization		D.b.h. class					
Sawtimber	Topwood	10	12	14	16	18	20
Inches	Inches	Cubic feet					
6	4	37	14	7	--	--	--
6	5	28	10	4	--	--	--
8	4	207	64	30	--	--	--
8	5	189	57	24	12	7	5
8	6	--	--	--	9	5	4
10	5	--	--	--	40	21	13
10	6	--	--	--	35	18	11

1/ Basis--310 loblolly pines in the South Carolina Coastal Plain.

Table 6.--Average yard lumber grade recovery by log grade in the loblolly-shortleaf pine type

(In percent of rough green lumber tally)

Lumber grade	South Carolina Coastal Plain				Georgia Piedmont			
	Log grade				Log grade			
	1	2	3	4	1	2	3	4
B & btr	51	31	13	1	-	50	17	4
C	24	21	10	3	-	18	12	4
# 1C	23	34	29	8	-	26	35	25
# 2C	2	14	47	80	-	5	34	64
# 3C	(1/)	(1/)	1	8	-	1	2	3

1/ Negligible.

Log value can be estimated from the foregoing table. An easier method is by means of log quality indices which express grade and board-width recovery in a single number. This number is so derived that it states the unit value of all the lumber in a log when the unit value of No. 2 common 1 x 8 boards is taken as 100. Table 7 illustrates the use of the indices in arriving at log values. It also illustrates the very wide spread in value per M board feet of the lumber in high-grade logs ($171) compared with low-grade logs ($75).

Table 7.--Average lumber value by log grade for loblolly and shortleaf pine, South Carolina Coastal Plain Study

Interim log grades	Average log diameter	Average log quality	Price of #2C lumber	Lumber value per M b.f. of logs ($\frac{\text{Price \#2C x quality index}}{100}$)
	Inches	Index	Dollars	Dollars
1	18.8	244	70.00	170.80
2	14.7	190	70.00	133.00
3	13.2	146	70.00	102.20
4	11.1	107	70.00	74.90

SUSTAINED-YIELD PILOT PLANT

A 2200-acre pilot plant on the George Walton Experimental Forest near Cordele, Ga., is in its fourth year of operation. During the interval, this large-scale test of sustained-yield management in the longleaf-slash pine type has shown a gross annual stumpage return of $5.94 per acre. Two years before cutting began, an inventory showed only 1130 board feet per gross acre, part of which had been worked out for naval stores. Cuts as low as 500 board feet per acre have proven commercially feasible. In this typically understocked forest, strict area regulation will be impossible for some time. The worked-out older timber must be liquidated, leaving a preponderance of young age classes. At present, this irregular forest seems best suited for even-aged management by groups and stands.

As part of the development program on the pilot plant it was found that wide annually burned fire lanes provide the best protection in this area where people burn at will. This type of protection costs 79¢ per acre annually. However, it has resulted in practically 100-percent restocking of previously fire-swept slash pine sites. A growth rate of 500 to 750 board feet should result as the growing stock builds up.

FARM WOODLAND MANAGEMENT

Farm Woodlot in Tenth Year at Olustee

Most of the Station's research centers have had one or more experimental farm woodland tracts in operation for several years. The one on the Olustee Experimental Forest is in its tenth year of operation. Sawlogs, pulpwood, crossties, fuelwood, and posts were cut and sold annually at the stump. Gum was sold at the roadside. Over the 9 years 1944-1952, the average net return to the farmer was about $350 on 37 acres, or an average of $1.82 per acre for stumpage plus $0.77 per hour of labor for working up the products. The hourly figure has costs of tools and equipment deducted, but no deduction has been made for taxes, insurance, and other incidental costs.

The condition of this farm woodland has improved from year to year. For the first few years the volume cut exceeded the volume growth in order to clear the area of worked-out naval stores trees, which originally made up 25 percent of the merchantable volume. Since then, the growth has exceeded the cut (fig. 10). Basal area has increased about 10 square feet per acre, number of trees per acre has increased about 50 percent, and present growth is at least 30 percent more than it was in 1944-45. The yield of gum has increased from an initial 156 barrels per crop to 225 barrels per crop, reflecting the faster growth and increased vigor of the trees.

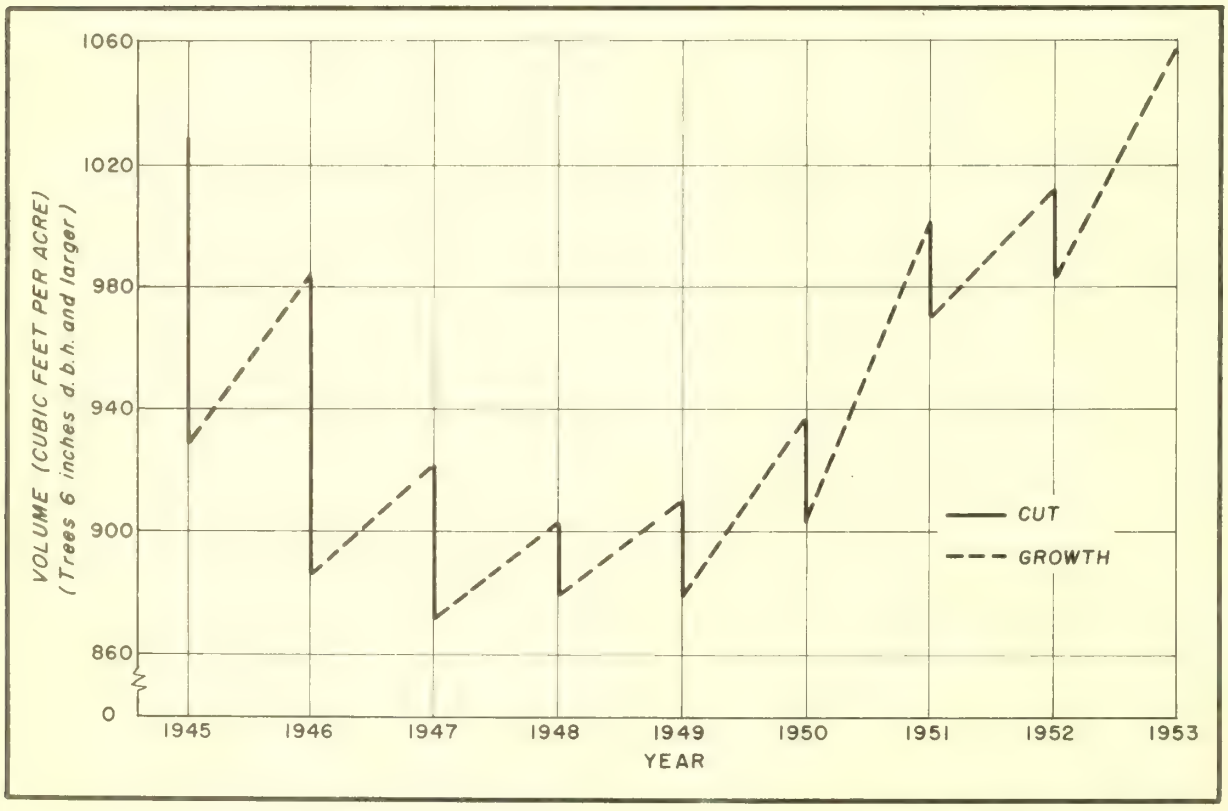

Figure 10.--Trend of growth and harvests on the 37-acre Olustee Farm Woodland. Heavier cuts were made at first to remove worked-out trees and other poor growing stock.

LARGE-SCALE TESTS OF MANAGEMENT SYSTEMS

Included in the program at five research centers are comprehensive term tests of management systems. Altogether there are 166 areas or compartments ranging from 30 to 100 acres in size. Their primary objective is to give timberland owners and managers adequate information as to desirable systems of handling timber in keeping with basic management objectives. As a sample, the set of treatments that are being compared in one large-scale test of management systems of loblolly pine is shown in table 8.

Table 8.--Design of large-scale test of management systems for loblolly pine on the Bigwoods Experimental Forest in North Carolina

Even-aged management					All-aged management		
Minor treatment	Major treatment				Minor treatment	Major treatment	
	Short rotation[1]		Long rotation[2]			Residual volume[5]	
	Seed tree[3]	Strip[4]	Seed tree[3]	Strip[4]		High	Low
	Number of compartments					No. compts.	
Extensive stand improvement					Stand improvement		
With fire	3	1	1	1	High level	2	2
Without fire	3	1	1	1	Low level	3	3
					None	1	1
Intensive stand improvement							
With fire	3	1	1	1			
Without fire	3	1	1	1			

1/ 30-40 years. 2/ 60-70 years. 3/ 8-10 seed trees per acre. 4/ Leave strip 1-chain wide; cut strip 3-chains wide. Final cut 3-4 years after initial cut. 5/ 5-year cutting cycle.

Obviously, the ultimate results from these studies will not be available for a number of years. In the meantime, they serve as excellent demonstrations of various management systems, and produce many worth-while interim results. For example, much of this Station's recent information on the reproductive habits of loblolly pine has been gained from this large-scale test of harvest cutting methods at the Bigwoods Experimental Forest. Furthermore, all

the logs used in the development of the Interim Southern Pine Log Grades came from cuts on the Hitchiti and Santee Experimental Forests. In addition, the compartments are convenient as pilot plants for results obtained from sample plots or other limited tests. Much of the large-scale testing of prescribed burning, poisoning, and other cultured measures has been done on these compartments.

Of somewhat academic significance are the interim financial returns realized from the sale of stumpage and products obtained from the compartments as a consequence of prescribed treatments. An example may be taken from the records at the Santee Experimental Forest located in the South Carolina Coastal Plain. Initial formative cuts on 1109 acres of loblolly pine divided into 28 compartments have yielded an annual gross return of $9.80 per acre for stumpage. This is impressive considering that most of the early treatment was designed to make the area even more productive in later years.

NAVAL STORES

Development of Acid Stimulation

Some small exploratory studies in the effect of strong acids on gum flow were begun in 1936. This work was not pushed, as labor was plentiful in the gum naval stores industry. But World War II disclosed a real need for a labor saving method of turpentining. As the various aspects of acid treatment became apparent, more and more efforts were concentrated on the problem. By 1946 some commerical benefits began to appear, largely by way of pilot plant operations. By 1950, a good practical technique had been developed that any woods laborer could understand. Also, substantial benefits had become apparent to the whole gum naval stores industry. Since then, research has been concentrated on various refinements to the basic technique.

An estimate of the relation between the cost of development and the resulting benefit to gum producers is illustrated in figure 11. As shown, all the expenses of a decade and a half of research were repaid during the first 5 years of commercial use. And the benefit to industry this year is about 20 times the current allotment for research.

Fundamental Studies

Turpentining reduces the growth of trees, but the profit on gum is many times greater than the loss resulting from reduced wood increment. During the past year, quantitative data were obtained for the first time on the loss in wood increment resulting from the use of bark chipping and sulfuric acid treatment on young slash pines in plantations. On 20-year-old trees 10 to 11 inches d.b.h., current annual increment on worked trees was about 73 percent of that on round trees during the first season of turpentining. The increment was nearly the same for both the bark-chipping, acid-treating method and the wood-chipping method.

Tests of new chemicals as possible replacements for sulfuric acid in treating naval stores streaks have been continued, but none has yet been found practical.

New Methods in Testing Stage

Preliminary tests indicate that the labor costs in gum production might be reduced by more intensive methods of working trees over shorter periods of time. Experiments are under way to determine whether the labor requirements can be reduced by using higher streaks and higher concentrations of sulfuric acid with fewer streaks per year or with fewer years of work per face.

Proven Methods

Tests of different streak heights and experience of commercial gum producers have demonstrated that for most operations 3/4-inch is about the optimum streak height for use with bark chipping and treatment with 50 percent sulfuric acid at biweekly intervals on both slash and longleaf pine (fig. 12). This technique will permit 4 years of work on a face without reaching the "pulling stage."

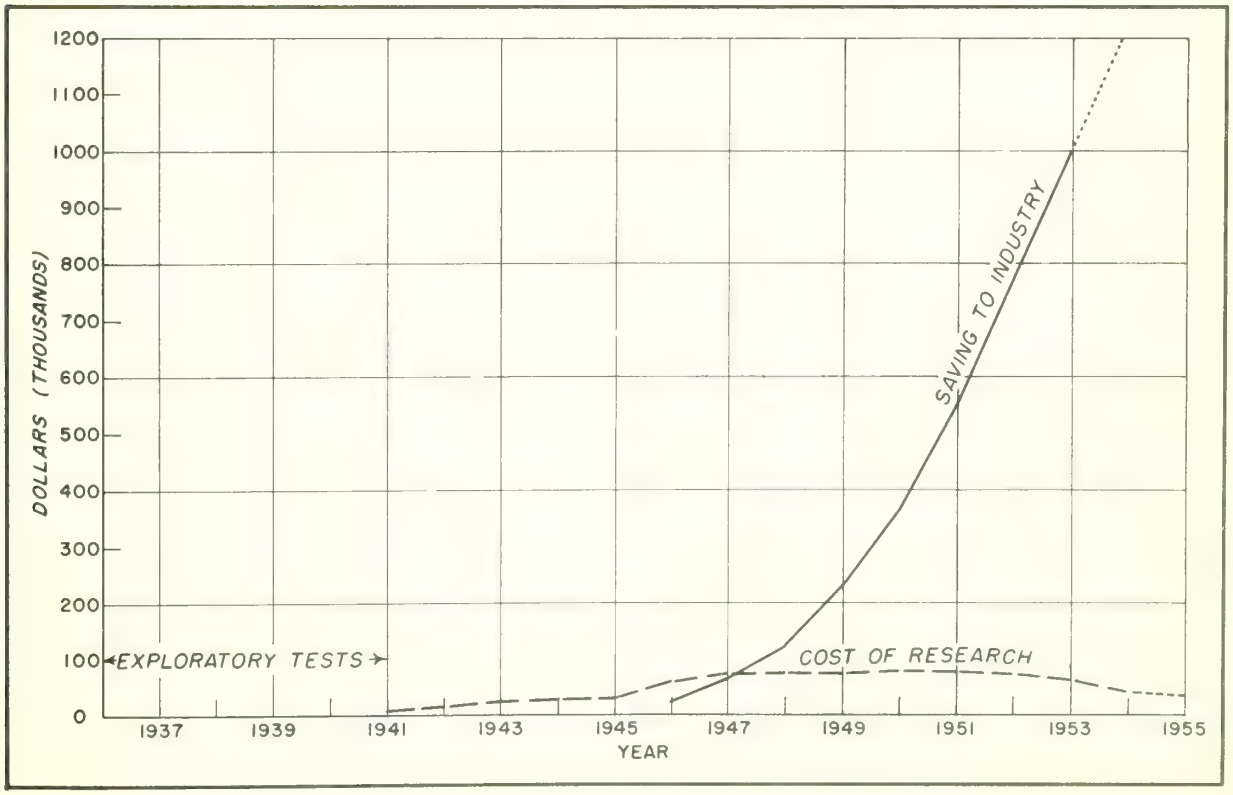

Figure 11.--Relation between cost of research and benefit to gum naval stores industry from development of bark chipping and acid treatment. Potential benefit estimated at 2-million dollars or more annually to be reached in 1960.

Figure 12.--A gum farmer using the bark chipping and acid treatment method of turpenting. The bark hack, spray bottle, 2-quart cup and spiral gutter (covered by cup apron) were all developed by research at the Station.

A major advance in gutter installations is the use of spiral gutters attached to the trees with double-headed nails. Advantages are:

1. Increase in gum yields of about 20 percent more than those obtained by use of gutters inserted into broad-axe cuts.

2. The same gutters and nails can be used for the virgin installation and for the successive raised positions on a face and thus reduce the cost of materials.

3. The gutters can be easily and economically removed after turpentining is completed. This makes possible the sale of the tree at full stumpage value without a deduction for a jump butt. For landowners who work their trees with modern turpentining techniques, this means an advantage of more than $4,000 on every crop of 10,000 naval stores trees sold for sawlogs.

Equipment Development

The elevation of gutters and cups on a turpentine face has always been a troublesome and expensive chore on commercial naval stores operations. To make this job easier and more economical, a new combination tool has been developed which permits one man to do the entire job of removing nails and gutters and installing them at the higher level. Because of the limitations of existing tools, this job is usually a two-man operation.

The new tool has a specially designed claw on one end to remove double-headed nails without bending either nails or gutters. On the other end is a claw for removing cup nails. Opposite this claw, a hammer head is attached to the tool for driving both cup nails and double-headed nails. Hence, one man can do both the removal job and the re-installation.

After the tool is thoroughly tested, a search for a manufacturer will be made. The tool probably will be available commercially by the end of 1954.

FOREST ECONOMICS

Timber Inventory of Georgia Completed

On October 30, 1953, the timber inventory of Georgia was finished. During the year field work was completed in fifty-one counties located in the northern Piedmont and mountain areas. Field crews measured the timber on 1,870 sample plots, and the area of forest land surveyed amounted to 6.4 million acres. Cooperation was received from the Union Bag and Paper Corporation, the Georgia Forestry Commission, and the University of Georgia School of Forestry.

Large Increase in Forest Area of Georgia

The resurvey of Georgia revealed a 12-percent increase in forest land area since the original Forest Survey of 1934-36. This increase amounted to 2,624,100 acres, making the present forest area of the State 24,056,600 acres. Reversion to forest was greatest on the idle and abandoned farm lands of the Piedmont, but there were also increases in the Coastal Plain and mountain areas. One important use for this new forest area estimate will be to provide the Georgia Forestry Commission with a reliable and up-to-date base for computing costs of fire protection.

Area	Forest land increase (Acres)
Coastal Plain	270,800
Piedmont	2,086,100
Mountains	267,200
State	2,624,100

Timber Supply Declines in Central Georgia

Portable sawmills have long been active in the lower Piedmont of Georgia. In recent years this area also has provided large quantities of pine pulpwood for local pulpmills. The trend in timber supply is of direct concern to these industries, as some have large investments in permanent plants. Results of the latest timber inventory show cause for concern. In the period between the original survey of 1936 and the resurvey of 1952, sawtimber volume decreased 31 percent and the volume of all growing stock 5.0 inches d.b.h. and larger decreased 14 percent. Comparable decreases for pine were 38 and 20 percent. There is evidence that the supply of hardwood timber is beginning to increase, as growth exceeded drain in 1952. Pine timber was still being overcut. Inventory data show clearly, however, that there is a marked increase in the number of young pines. If the downward trend in the supply of pine timber is to be reversed, public and private forestry programs must provide for improved protection and management of these young stands.

New Forest Statistics for Southeastern North Carolina

The resurvey of Southeastern North Carolina (Survey Unit 1) completed in 1953 provides up-to-date information on the timber supply situation. Since 1937, when the original survey was made, there has been a slight decrease in forest area. Pine forests now occupy nearly three-fourths of a million fewer acres than in 1937. There is better stocking of young timber, both pine and hardwoods, but pine trees 12 inches in diameter and larger have decreased in number. Only 5 percent of the commercial forest land is well stocked with sawtimber. Simce 1937 the volume of hardwood sawtimber increased 10 percent, whereas pine sawtimber decreased 10 percent. During the period between surveys the volume of timber cut has apparently been greater than at present, for the current relationship of growth and drain leaves a margin which is building up the growing stock. Whether or not this will continue will depend upon the future demand for wood products and the effectiveness of forest management practices aimed at increasing the supply of timber.

Unused Slabs and Edgings at Small Sawmills

Recently there has been considerable interest in the possibilities of pulping sawmill slabs and edgings. As a result, log barkers and chippers have been installed at a number of lumber plants. However, the great bulk of slabs and edgings is produced at sawmills too small to justify the installation of such equipment. The fact that there are thousands of little mills and that many are portables is a further complication. Current investigations in a typical area of the pine roofer belt in South Carolina are designed to shed light on salvage problems at small sawmills.

One of the first subjects investigated was the already existing uses for slabs and edgings. Before gasoline and diesel power units were introduced in the Thirties, a considerable quantity was burned to generate steam for sawmills. Now, the only use is home fuel. With the extension of electricity to rural areas and increased use of oil and bottled gas for heating and cooking, even this demand has declined greatly. In the study area, only 27 percent of the available volume is actually sold for this purpose. The price of uncut slabs at the mill site was found to average only $1 a cord, and the highest price noted was only $3. Fifty-four percent of the sawmill residues are left to rot on the ground. How the sawmill operators and landowners disposed of the slabs and edgings is shown below:

	Percent
By the sawmill operators:	
Sold as fuel	8.4
Used as home fuel	2.4
Given away	2.6
By the landowners:	
Sold as fuel	18.8
Used as home fuel	11.5
Given away	2.4
Unused	53.9
Total	100.0

Pulpwood Prices and the Value of the Annual Cut

Rough pine pulpwood, which sold for $13.75 per cord f.o.b. railroad car in most sections of the Southeast during 1953, averaged only $7.15 per cord 10 years ago in 1943 and only $3.55 15 years ago. These values are from a price series covering the period 1938 to 1952 inclusive. The series was prepared from reports furnished by seven representative pulpmills that purchase about half the pulpwood currently produced in the region.

In 1952 the average price of all the pine pulpwood purchased (including railwood, truckwood, and bargewood) was $13.90 per cord. Pine pulpwood production for the year in Virginia, the Carolinas, Georgia, and Florida amounted to 7 million cords. Therefore, it was worth $97,300,000. If prices elsewhere in the South were similar, the total harvest of pine had a value of $177,400,000. Including hardwoods, the South produced about $200,000,000 worth of pulpwood.

A Method of Calculating the Effect of Log Size on the Cost of Sawing Pine Lumber

It has been estimated that 15 to 25 percent of the lumber sawed at small sawmills is produced from marginal or submarginal logs--logs that yield no profit to the lumberman and frequently little or no return to the landowner. Operators who sell their lumber on a green, mill-run basis are most likely to fall into this uneconomic practice. This happens because they receive the same price for all grades and sizes of lumber. What they overlook is that their output and sawing costs are related to log size even though the value of their lumber is not.

The results of a time study in the South Carolina Piedmont offer operators of mill-run pine sawmills a method of calculating their sawing cost per thousand board feet for logs of any size. By comparing the calculated costs with the price of lumber, each operator can determine the marginal size of log for his mill and crew. He can also compare logs of various diameters and lengths as to the profit or loss involved in sawing them. Results of the study will be published in 1954.

WATERSHED MANAGEMENT

Integration of Water and Timber Management

Recent droughts have raised anew the question whether summer streamflow can be increased through watershed management. To find the answer, the Southeastern Statuon is studying changes in streamflow brought about by cutting vegetation, defoliation during the summer months, and by changing the composition of the forest stand. A special review of experimental results was carried out during 1953 to summarize what has been found out on experimental watersheds at the Coweeta Hydrologic Laboratory.

Results to date show that cutting of old-growth hardwood stands definitely increases total water yields as summer streamflow under the high rainfall conditions of the Southern Appalachian Mountains. In the application of this fact, however, it is the amount and duration of favorable effects that become of practical interest.

In experiments conducted at the Coweeta Hydrologic Laboratory the largest sustained increase in water yield was measured where all tree and other woody vegetation was cut, and where subsequent sprouts were cut back each year in midsummer. In this case, streamflow was increased the first year by an amount equal to a volume of water 17 inches deep over the entire watershed. Since the original cut, the major woody sprouts have been cut back, but there are now herbaceous plant species, low briars, and vines invading the watershed. This invasion has changed the increase in streamflow from the original 17 area-inches for the first year after cutting to only 9 inches increase 12 years later. This was primarily an orientation study to establish the maximum effects on water yield that can be obtained through cutting an old-growth hardwood forest. For applied watershed management it would not be necessary or practical to aim at such large increases. Increases of only a few inches during the late summer and fall would be of tremendous value during drought years.

On another similar watershed all woody vegetation was also cut to begin with, but then the forest was allowed to grow back naturally. The first year after cutting, streamflow increases were comparable to those mentioned above, but this favorable yield diminished rapidly for the first 3 years, after which the decline was more gradual. The annual increase in yield for the 3-year-old coppice forest was 10.7 inches; after 7 years regrowth 8.1 inches; and at 12 years 4.9 inches.

On still another watershed where only the laurel and rhododendron understory was cut from an old-growth hardwood stand, the average increase in water yield for the first 2 years was 3.6 inches. The third year it was 2.4 inches and for the 4th year only 1 inch. During the 5th year any increase over the precutting period was insignificant, probably not because of regrowth of the understory, which was slow, but rather because of expansion of the roots of trees to use the available water.

Cutting a strip along the water course also produced significant gains in streamflow during the summer months only. On one 20-acre watershed where a narrow strip was cut along the stream (fig. 13), increases in

Figure 13.--An experimental watershed from which streambank vegetation was cut to see whether flow would be increased and if so how much and how long.

water yield were 365 to 475 cubic feet per day during the growing season of the first year. For the same period in the second year following cutting, average daily gains were from 135 to 300 cubic feet. By the third year sprout vegetation had become well established and no further increases were detected.

The above four experiments give some idea of the magnitude and duration of increases in streamflow obtained by cutting forest vegetation in the high rainfall area of the Southern Appalachian Mountains. It does not follow that the similar results would be obtained under different soil and climatic conditions. These results serve only as a guide to streamflow increases obtained through cutting in mountain hardwoods.

For small industrial or municipal watersheds where current requirements exceed the streamflow by relatively small margins and for short periods of time during the summer months, watershed management involving control of vegetation by cutting merits careful consideration as a feasible alternative to expensive reservoir installations. Where no suitable reservoir sites are available, watershed management practices are the only procedures available. As already mentioned, even a small increase in streamflow can be quite important. For example, one area-inch increase of water from one square mile is equivalent to 18,424,000 gallons. This would supply a population of 5000 for more than 36 days with 100 gallons per capita per day.

The cutting of forest vegetation specifically to increase water yields may be costly. Other means of reducing the vegetation such as the use of silvicides, gas, and sprays are being tried. Doubtless the most feasible approach is to reduce the stand density by harvesting wood products in such a way that water yields are increased at times when shortages are most likely to occur.

For the present, the important step is to include a consideration of water resources in all forest management plans. The logical step is to integrate what has been learned about the general effects of cutting on streamflow with practical silvicultural systems for managing specific forest stands. Also, the time of year when harvest cuttings are made is an important consideration, so that periodic cuttings will be most beneficial to summer streamflow.

Although cutting increases streamflow, experiments so far indicate that the soil profile under a forest cover is particularly effective in the control of storm water and the storage of ground water. The conclusion is that a managed forest constitues the most favorable type of watershed cover, providing cutting practices are aimed at maintaining a suitable stand density

The Station is now preparing a report of 20 years' results of watershed management experiments on the Coweeta Hydrologic Laboratory, to be completed in 1954.

Future Watershed Experiments Recommended

During 1953 a special program conference was held for the purpose of discussing plans for future watershed experiments. The conference was attended by representatives of both the Administrative and Research branches of the Forest Service. The general recommendations included the following points:

(1) Present studies should be expanded to include further tests of methods for managing commercial timber stands to insure favorable water yields and at the same time provide reasonable returns from forest products.

(2) Additional studies are required to compare the relative effectiveness of well maintained grass sod with forest cover for watershed protection. Similarly, a comparison is needed of hardwood forest and a pure stand of conifers.

(3) On experimental watersheds that now exhibit serious deterioration of water resources due to unfavorable land-use practices, the rate of recovery of soil and water resources brought about by recommended improved practices should be observed.

Information and Education Activities

A large portion of staff time during the year was taken up by visitors at the Coweeta Hydrologic Laboratory. Seventy-five tours of the area were arranged for 864 visitors. One hundred foreign technicians came from 20 different countries, some spending from 1 to 2 weeks. There are also six university graduate students affiliated with the Coweeta Laboratory in the preparation of thesis material. In addition, the staff was called upon to conduct three training sessions of several days each for in-service personnel. Talks before technical organizations and civic clubs required considerable overtime, and operation of the basic research program was curtailed by these demands on the time of the technical staff.

Improvement of Piedmont Forest Soils

At the Calhoun Experimental Forest in South Carolina, an entirely different approach is being made to watershed management. Here the problem is one of rehabilitation of the degraded and abandoned cotton lands of the southeastern Piedmont. Studies are under way on present soil problems and to develop management programs for soil improvement. These studies are directed toward finding out how to increase infiltration and storage of water in the soil by improving the soil structure. During 1953, results have been obtained on the comparative effects of litter from different plant species on a basis of rate of decomposition and incorporation of these organic materials and plant nutrients into the soil profile.

Pure pine litter was resistant to decay and only slightly attacked by insects. Pine litter tends to accumulate at the surface because the type of biological activity under pure pine does not result in incorporation of the litter into the mineral soil. On the other hand, litter from hickory and yellow-poplar is subject to rapid decomposition and incorporation as organic matter into the mineral soil.

In mixed pine-hardwood stands where the hardwood species consist of redbud, dogwood, maple, yellow-poplar, and hickory, the litter decomposes rapidly and is easily incorporated into the mineral soil.

The relative rates and ease of decomposition of the surface organic layers are substantiated by measurements of the organic matter content of the mineral soil. The quantity of organic matter in the surface foot of

mineral soil under the pine stands studied averaged 31,770 lbs., under pine-hardwoods 53,353 lbs., and under all hardwoods 65,573 lbs. Since nitrogen in the soil is closely correlated with organic matter content, the same relative relationship holds for nitrogen as for organic matter.

The type of humus layer present is also useful in describing the hydrologic characteristics of forest soil. Soils where organic material has been incorporated have greater porosity, can store more water, and transmit it more rapidly than bare soils where incorporation has not taken place.

The nature of incorporation of organic material into the forest soil has a direct relation to the use of prescribed burning in the Piedmont. It was also found that the nature of the surface organic layers will influence the intensity of the fire. Loose pine needles are more easily consumed than a compact layer of hardwood leaves. Removal of the forest floor by fire is least serious where organic material has been incorporated into the soil because the properties of the mineral soil are such that they can absorb and transmit water even when exposed. Also, less of the nutrient capital is destroyed by fire on sites where much of the litter is currently taken into the mineral soil and does not accumulate at the surface. When fire consumes the litter layers, the elements are either volatilized or left in the ash, in which form they are susceptible to leaching and washing away. If they are lost to the site after a fire, the effect on the fertility will be most pronounced where the reserve of such material in the mineral soil is least.

Thus it has been shown that the organic layers of forest soils are a valuable diagnostic tool for timber and watershed management. They can be changed by modifications of the vegetation on the site. Studies to date show that where Piedmont forest soil needs improving, steps should be taken to manage the stands so that some rapidly decomposable hardwood litter will be incorporated. Such conclusions may serve as a brake on the enthusiasm of foresters who advocate pure pine stands on eroded Piedmont farmlands.

FIRE RESEARCH

New Danger Meter Developed

A new fire danger meter, type 8 (fig. 14), developed largely by J. J. Keetch, Region 7 cooperator, has been designed to replace type 5 used by fire control agencies throughout the Northeast. The latter type has served many useful purposes in measuring daily danger in fire prevention, as a guide to woods closure, in comparing seasons and field units, and in organizing for presuppression and control. However, as greater familiarity was gained by field men in these many uses, the need for greater precision in measuring danger became apparent.

Because a large volume of accurate records was available for analysis as a result of long cooperation with the northeastern states, it was possible to devise a meter that retained the basic principles of the type 5 meter but

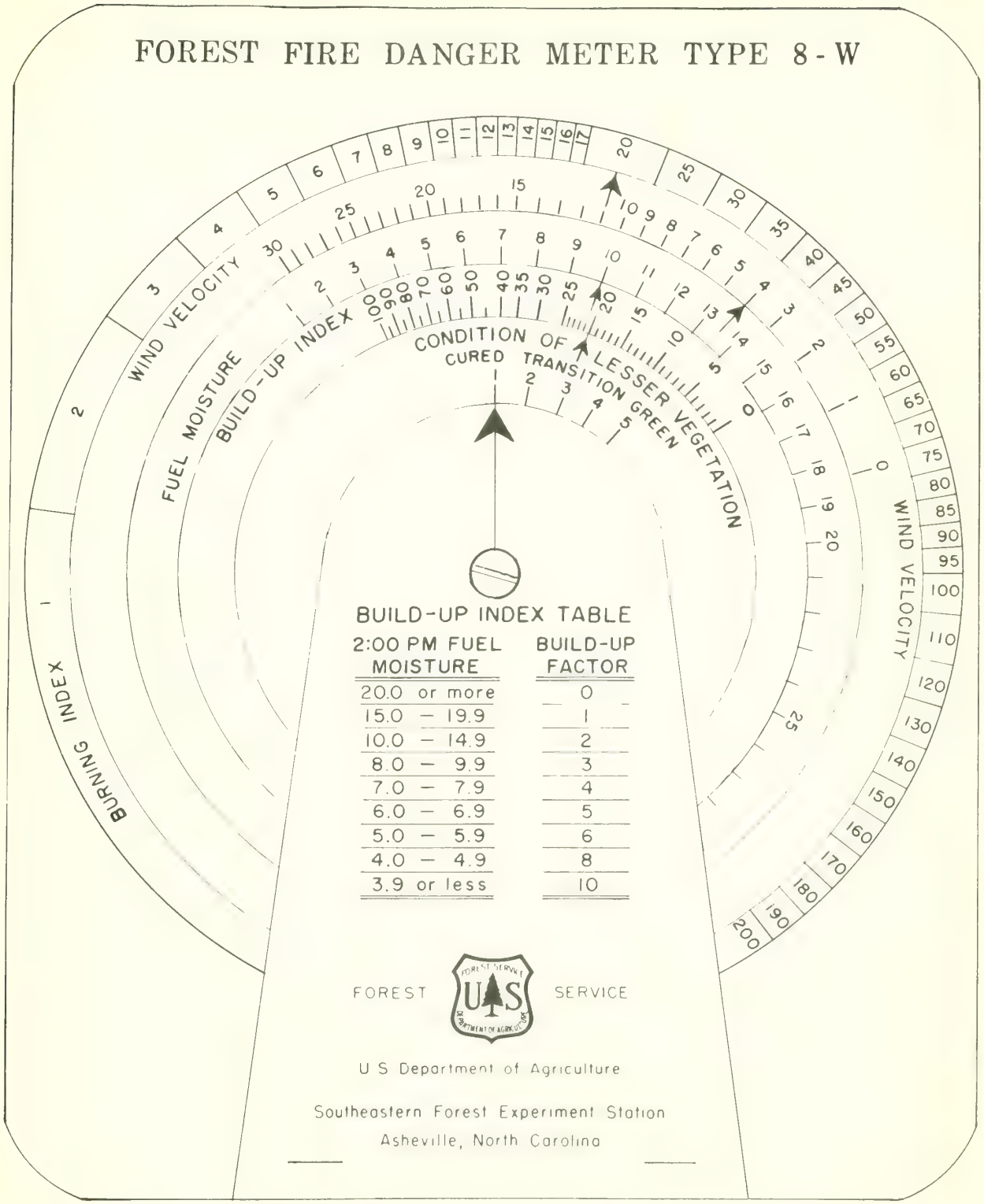

Figure 14.--Type 8 danger meters were adopted by all fire control agencies in the northeast January 1, 1954. The new meter gives a better estimate of daily burning index and fire danger build-up.

which had several new features. For example, by replacing the discs showing days since rain and last rain, inches with a disc showing build-up index, greater accuracy is obtained during extended rainless periods. Also, the transition period in condition of lesser vegetation has been expanded into three classes. This makes the change from one condition to another less abrupt and more consistent with actual field conditions.

The build-up index is a notable improvement because it indicates the progressive drying of the lower fuels, which fuel moisture sticks are unable to do. By cumulating daily "build-up factors," an increase or decrease in the severity of conditions during a critical period is readily apparent. To some extent the index is also a measure of resistance to control in that as the 100 point is approached fires become progressively more difficult to hold because of breakovers. Deeper lines must be cut and more caution used lest smouldering material burn under control lines. Mop-up also becomes increasingly more difficult.

"Blow-up" Fires

Good progress was made during 1953 in the study of the exceptional class of fires often described as "blow-up" fires. This descriptive term clearly implies the idea of suddenness and to some extent the idea of unexpectedness, from the standpoint of the potential danger of these erratic fires to suppression crews.

The problem of extreme fire behavior is complicated by a large number of variables such as fuels, stand type, and topography. It is made more complex by the less known atmospheric variables and their interactions. Its nature can be illustrated best by listing what we now know of both the consistent and inconsistent features of fire behavior:

1. Most severe fires and a considerable number of blow-ups occur during the middle of the afternoon on sunny days. On such days the atmosphere is often turbulent and unstable to a height of several thousand feet. However, some of the worst forest conflagrations in the United States have either occurred at night or reached the peak of their intensity at night (usually between sundown and midnight). At this time the lower layers of the atmosphere (up to 500 feet or more) are usually stable.

2. Some of the worst western fires in the past 15 years have been in rough country, which indicates that topography is a dominating factor. On the other hand, there have been conflagrations such as those that occurred many years ago in the Lake States, which burned in nearly flat or rolling country. Some of these conflagrations have been compared to "tornadoes of fire."

3. An intense fire may occasionally spread rapidly across slope or downslope at night in the general direction of the cool downslope winds. Yet this same rapid downslope spread may happen in the middle of the afternoon when surface winds, if any, would be upslope. The Brasstown fire of March 30, 1953 in South Carolina traveled across drainages (upslope and downslope) as though they did not exist.

4. Instability in the atmosphere seems to be closely related to extreme fire behavior; yet on a large proportion of warm, sunny days the atmosphere is unstable. Fires do not always build up to extreme intensity on such days.

5. Many intense fires have been accompanied by high winds; but some of the most dangerous and erratic fires have burned when the wind speed was not especially high.

6. High temperatures and low relative humidity accompany a large proportion of severe fires, but some of the most intense and rapid spreading fires burn when the temperature is low and falling. The fires in the Southeast in the fall of 1952 are examples.

7. Prolonged periods of drought and dry weather show a strong correlation with intense hot fires, but the Brasstown fire burned only a week after nearly two inches of rain had fallen on ground well charged with winter rainfall.

8. The amount of fuel available to a fire is an important factor in its behavior. At times the effect on fire intensity of an increase in quantity of fuel appears to be considerably greater than would be expected from the actual fuel increase itself.

9. Arrangement as well as quantity of fuel is important. Extreme fire behavior seems most likely to occur in dense conifer stands. Intense fires also build up in stands of evergreen brush, and can readily cross swamps if the brush is dense enough.

10. On those fires most likely to be designated as blow-ups (owing to the sudden and often unexpected build-up of turbulent energy), there is an obvious and well developed convection column which may extend high in the atmosphere.

11. Large fires exhibiting extreme behavior have been known to put up convection columns to a height of 25,000 feet or more. Since 70 percent of the total mass of air is below the tops of such convection columns, these fires have literally "pierced the atmosphere." They are volume phenomena and have storm characteristics like certain other disturbances in the atmosphere. This in part seems to explain why they do not conform to the "rules" of fire behavior. These "rules" are based on the far more frequent ordinary fire, which is pretty much a surface phenomenon.

The preceding statements illustrate the baffling nature of the exceptional fire that does not conform to the accepted principles of fire behavior. They also show the magnitude of the requirements that an effective solution of the problem must meet. However, the problem may not be as difficult as it appears. Our work thus far indicates that those factors which determine the rate at which a fire produces kinetic or turbulent energy may be the elements needed for an overall solution. These factors are stability conditions in the atmosphere, wind speed, wind shear, and available fuel for the fire.

The thermodynamic method, mentioned in last year's annual report, still appears to be one of the most effective tools in the study of the exceptional fire.

FOREST UTILIZATION SERVICE

Cooperative effort was the guiding motive of the Forest Utilization Service in 1953. Cooperation with the states, with other government agencies, with industry, and with individuals keynoted practically every accomplishment during the past year.

An outstanding example was the launching of the Hickory Task Force at Clemson, South Carolina, in April. About 55 representatives of government, states, universities, and industry met to organize eight subject-matter committees and to lay the groundwork for a 3-year program involving research and report preparation. An August meeting of the Executive Committee crystallized the plans and started work. Already, more hickory is being used although the first report has not been published.

Cooperation with the North Carolina Department of Conservation and Development started with a compilation of information to attract new wood-using industries and continued with a cooperatively financed study to ascertain the quantity, quality, and location of the various types of wood residue from primary wood-using industries in North Carolina. This study will be completed and published by the State in 1954.

The increasing scarcity of high-quality timber favors the development and use of log and tree grades. In 1953 the Forest Utilization Service conducted courses in pine and hardwood log grading for the Florida Forest Service and the Appalachian Lumbermens Club. In cooperation with the latter, field studies demonstrated the Forest Products Laboratory hardwood log grades, utilizing a log grading stick developed by Englerth and Ostrander. Also, analyses were made of data collected by a lumber company in applying the southern pine log grades.

Working with North Carolina, South Carolina, and Georgia State forestry personnel, the Utilization Service conducted eight short courses in sawmilling. These were supplemented by numerous on-the-ground visits to small sawmills to assist in milling and seasoning problems.

In cooperation with the School of Forestry at North Carolina State College, an 8-day dry-kiln course was conducted, with Forest Products Laboratory assistance. Also, a 2-day review of the dry-kiln course was given to members of the Southeastern Dry Kiln Club, at Raleigh, North Carolina. The Forest Utilization Service and Tennessee Valley Authority also helped small industries in the mountains in developing plans for dry kilns.

The Forest Utilization Service personnel helped in the work of the Wood Preservation Coordinating Council, an organization of southern schools interested in wood preservation research. This organization was started in 1946 by the Tennessee Valley Authority and has taken a leading role in preservative research in the Southeast. In addition, the Forest Utilization Service conducted a short course in wood preservation for South Carolina forestry personnel.

With the assitance of the Forest Products Laboratory, the Southern Weighing and Inspection Bureau, and the Southern Furniture Manufacturers Association, a survey of furniture packaging methods was made at 20 plants in Virginia and North Carolina.

The Southwestern Forest Experiment Station and a Virginia company making cedar chests cooperated with us in preparing a report on the slicing of Utah and alligator juniper veneer, which may lead to new industrial possibilities in the Southwest.

Six new automatic wood-burning furnaces for tobacco barns were constructed on farms in North and South Carolina, and although two burned down because of improper construction, the others performed satisfactorily. Assitance to the owners of these installations resulted in improved techniques in construction and operation of the furnaces. A blower was installed on a sawdust burner used for curing tobacco, and it functioned exceedingly well for severl cures.

A conference on the use of wood waste as a soil conditioner was arranged and was attended by Forest Service and other government personnel in Washington. Arrangements were made to discuss this problem with Soil Research Committees over the entire country, to encourage needed research at State Agricultural Experiment Stations.

In cooperating with the over-all program of the Experiment Station, the Forest Utilization Service assisted the Timber Resource Review in a survey of wood residue in the woods and at sawmills over the entire Southeast. Work was done with the Tidewater Research Center on an analysis of wood utilization problems in that area. The Forest Utilization Service assisted in a general inspection of the Lake City Research Center. Personal attention was given to 16 foreign visitors interested in southeastern wood utilization problems; these and other visitors were conducted through the territory for specific studies, informational trips, or inspections. Program contributions were made at Forest Products Research Society meetings, county agent meetings, and others. More than 200 inquiries for information were handled by letter, telephone, and personal contact. And new problems were uncovered which led to more research, in accordance with the liaison functions of the Forest Utilization Service.

FOREST RANGE

Determining the value of forest forage and how grazing can be efficiently integrated with timber production are the main objectives of the Station's range research.

Research has shown that grazing in the southern mountain forests damages both land and trees, and seldom pays. To a certain degree the same holds true for forest grazing in the highly erodable Piedmont. But on the wide belt of Coastal Plain pine land extending from Virginia through the Carolinas, lower Georgia, Florida and Alabama, conditions are quite different. Here, forest lands are relatively level and sandy or swampy. Forage production is greater and the valuable pines are not palatable to cattle, which have ranged these forests since the time of the Spaniards. Today,

cattle numbers in the Southeast are increasing faster than in any other region of the United States. The average Coastal Plain forest owner is concerned primarily with growing timber, but he is also interested in the possibilities of added income and fire protection from grazing--particularly when the forest stands are understocked, as many of them are.

For these reasons, the Station's forest grazing research is confined to the Coastal Plain. Studies have been restricted to pine types where abundant herbage and minimum erosion offer the greatest possibilities for successful integration of cattle raising and timber production. Within the pine types, research has been concentrated on the two outstanding forage types of the region, switch cane and wiregrass. Cane is the most productive and nutritious type; wiregrass is the most extensive.

Studies in the cane type are being conducted in the territory of the Tidewater Research Center in eastern North Carolina. Work Centers are at the Frying Pan Experimental Forest Range in Tyrrell County, and at the North Carolina Tidewater Test Farm in Washington County. Wiregrass research is centered at the Cordele-Tifton Research Center in south Georgia, with principal grazing studies at the Alapaha Experimental Range in Berrien County.

All of the Station's range research has been conducted cooperatively with other federal bureaus (BAI and BPISAE) and with state agencies. North Carolina State College and Agricultural Experiment Station, and North Carolina Department of Agriculture have cooperated in studies involving the cane type. Georgia Coastal Plain Experiment Station cooperates in studies of wiregrass range in south Georgia.

Additional range research was started this year in southern Florida as a result of special appropriations by the Florida legislature, and contributions from the Collier Company and the Atlantic Land and Improvement Company. Past use of forest land in southern Florida has emphasized grazing at the expense of timber production. As a result, many forest stands have been eliminated, and remaining stands are poorly stocked with trees. Some people in this area believe that grazing is more profitable than timber-growing, whereas others hold the opposite view. Still others maintain that cattle and timber production should be combined for greatest total income. Range and forest management research are working together to determine best uses and practices for maximum returns.

CANE RANGE

The cane forage type is most often associated with pond pine in areas burned periodically throughout the past. It also occurs with lowland hardwoods and with loblolly pine on moist sites. Cane sites are usually wet much of the year, but during occasional droughts fire hazards are extreme because of the density and height of the cane and associated shrubs. Forage values are also high. Consequently, grazing in this type can be profitable and at the same time beneficial to the forest.

Progress in Cane Management

From early colonial times cane has been recognized as one of the best types of native forage in the Southeast, but its growth requirements have not been well understood. Flowering and seed production are unpredictable--occurring after an indefinite period of years or decades. Furthermore, natural seedling establishment apparently is rare--the only published record of its occurrence, so far as we know, was from our North Carolina studies. Once eliminated, the chances for natural re-establishment of cane stands seem remote. Therefore, present stands of this valuable forage warrant proper management.

Previous experience had shown that cane is readily weakened and killed by overgrazing, but until published this year, specific guides to proper grazing were not available. Studies have shown that at least 40 to 45 percent of the foliage must be left unutilized at the end of the grazing season if cane vigor is to be maintained under continuous summer grazing. With continuous grazing, however, local overgrazing and range deterioration is difficult to avoid. Current results indicate vigor is more easily maintained with rotational grazing.

Cane Range is Highly Productive

An example of very profitable forest grazing from cane range in eastern North Carolina is shown in results published in 1953. Annual beef gains averaged 111 pounds per acre (for a 7-month season) under the optimum grazing rate for sustained forage production. Cows subsisted entirely on native forage three-fourths of the year, and produced 80-90 percent calf crops with calves weighing 370-400 pounds at weaning time. As an additional grazing benefit, total fuel was reduced 70 percent (from 14 to 4 tons per acre) by heavy grazing, and almost 50 percent by moderate grazing. These results obtained on non-stocked forest land suggest possibilities for immediate returns from such land while a forest is being re-established, and also for reducing the critical fire hazard which previously has discouraged reforestation in this area. These cattle returns, however, were better than average and required proper management of both range and cattle.

Cane Response to Fire

Interest in silvicultural applications of fire in forest types associated with cane is increasing. In fact, burning has been found essential for adequate regeneration of pond pine. How burning affects the cane stand is now being studied. Previous information showed that frequent burning decreased forage production. On the other hand, observations indicate that after about 10 years of fire protection cane stands get taller but tend to thin out and become less productive. In such cases winter burning will greatly increase the number of stems and decrease their height, but forage yields will be increased only if the cane is vigorous. Where cane had been weakened by previous heavy grazing, yields were further reduced by burning. How burning affects chemical composition and digestibility of the forage will also be determined in cooperative studies now under way. Experience obtained during the burning operation indicated that fire could be handled satisfactorily in the cane type at a burning index of 10 (meter type 5-W), but under more severe conditions cane fires were very hot and explosive.

Grazed Firebreaks for Wet Sites

During occasional droughts, fire hazard in cane and pond pine sites is extremely high and fires are difficult and dangerous to combat. In these extensive roadless areas, the cane and brush are often head high and very dense. Soft spots, stumps, and down timber make travel even in jeeps impossible. Conditions are so difficult that when fire plows are sent it, two cats usually go together so that one can haul the other out. Thus, fire control would be greatly facilitated by wide firebreaks and emergency access roads. Recently completed research indicates that grazed pasture strips can serve these purposes, and that income from cattle can thus help defray the costs of fire protection. On poorly drained sites, side ditching and slight crowning of the strips were found necessary to prevent the loss of the pasture stand from flooding. Several types of commonly available equipment are suitable for constructing such firebreaks. Common pasture species such as ladino and white clover, big trefoil, tall fescue and orchardgrass proved to be sufficiently fire resistant for this purpose. Aside from the selection of suitable species, the keys to a successful firebreak appear to be good seedbed preparation and adequate fertilization to insure prompt establishment of a pasture sod capable of controlling weed invasion.

WIREGRASS RANGE

The term "wiregrass" is commonly applied collectively to the grasses occurring in the longleaf-slash pine forest type. It is the most important type of forest range in the Southeast from the viewpoint of acreage and cattle numbers.

Wiregrass Range Has Limitations

The value and limitations of wiregrass range are indicated by results of grazing studies published in 1953 as USDA Circular No. 928. The nutritive value of this native forage is very low, especially in fall and winter. Burning increases forage quality and cattle gains during the spring and early summer, and is essential for efficient utilization of this type of range. But even with burning, the nutritional level is not high enough for most cows to breed successfully while nursing a calf. Consequently, one calf in 2 years is the rule, with calves weighing approximately 280 pounds at 7 to 8 months of age. A limited amount of supplemental feeding during fall and winter decreased death losses and increased calf weights, but did not increase calf numbers appreciably. Stocking conservatively on the basis of the burned acreage had a similar influence. Thus, a high-percentage calf crop from wiregrass range apparently depends on supplemental sources of nutrients in summer as well as winter.

Methods of Improving Cattle Performance

Providing a limited amount of improved pasture along with native range appears to be a practical solution to the problem of making effective use of cheap range and at the same time obtaining good cattle production. First-year results with this procedure produced calves approaching the weight of those from pasture herds, and up to 175 pounds heavier than the average calves obtained in previous range studies. Wintering cows at a high nutritional level (but with only range in summer) increased calf weights about

90 pounds over those obtained previously from herds wintered at a minimum level. Other practices are also being used to provide at least 3 levels of nutrition in summer and 2 in winter in order to establish the minimum requirements for high productivity of range herds. The first effects on calving percentage will be obtained next year.

Three years' results from south Georgia show that the quality of range forage can be profitably improved by introducing better forage species into the range. Improvement with lespedeza and carpetgrass has been most profitable, yielding an average of 86 pounds of beef gain per acre. Total improvement costs were equivalent to 46 pounds of beef gain, leaving a net return of 40 pounds of beef per acre annually over a 3-year period. Comparable net returns from unimproved range averaged 14 pounds of gain per acre annually. The improvement consisted of merely broadcasting seed and fertilizer on freshly burned range, and light refertilization annually (200 pounds per acre). More expensive practices involving brush chopping and disking, as well as forage species requiring higher rates of fertilization, gave greater returns per acre but lower net returns per dollar invested in improvements. In order to compare treatments and measure returns accurately, it was necessary to confine cattle entirely to improved range. In practice, greater benefits could be obtained by integrating the use of improved range with native range. The improved portions could well provide firebreak strips.

Tests in south Georgia have shown that revegetated strips offer considerable fire protection. White clover is particularly useful for this purpose because it produces succulent, noninflammable foliage during the winter and early spring in this region. Grazed sods of white clover and carpet or Dallisgrass have provided good fire protection from late January to early November. For the remaining 2 to 3 months, when the grass has been frosted and clover growth is limited, the additional protection of a disked fire line is needed to stop fire-creep even though fuel on grazed sods is scarce and fire control is relatively easy. Since needle cast destroys the effectiveness of disked strips and grazed sods for fire protection, firebreak strips should have no tree cover.

Needle cast also kills out the improved forage stands where tree stocking approaches 50 square feet of basal area per acre. Best grazing results have been obtained where tree basal area was less than 15 square feet. Also, forage yields have been highest on moist lowland sites. All in all, research is showing good possibilities for increased grazing returns from understocked forest land through range improvement, and at the same time obtaining additional fire protection.

Effects of Burning and Grazing Longleaf-Slash Pine Sites

How burning and grazing affect site factors such as vegetative and soil conditions has an important bearing on the question of integrating grazing and timber production. Vegetation responses in south Georgia during 7 years of grazing at full range capacity are summarized in Georgia Coastal Plain Experiment Station Bulletin 51 released in 1953. Soil changes measured after 9 years have been analyzed but not yet published.

Aside from the direct effect on small pine trees, no detrimental influences on understory vegetation were detected--from a forest viewpoint. Burning favored grasses and herbs by removing litter and checking brush

growth (in comparison with no burning). With both burning and grazing, the taller bunch grasses decreased, while low-growing grasses and herbs, and also gallberry, increased. Without burning, the grass cover decreased, and brush increased whether grazed or not. The combination of late winter burning followed by season-long grazing reduced herbaceous fuel 70 percent when measured in the fall.

Burning had no significant effect on these sandy soils so far as could be determined from the characteristics studied. Soil organic matter, pH, phosphate, and potash content, volume weight, infiltration and percolation rates, and water-holding capacity were essentially the same after 8 years of burning as after a similar period of fire protection (following previous periodic burning).

Grazing, likewise, had no detectable effect on the chemical constituents of the soil. However, grazing did influence physical characteristics significantly. Volume weight of the top 3 inches of soil was increased 5 percent, and infiltration and percolation rates were decreased about 60 percent. Water-holding capacity was decreased 4 percent. These measurements reflect slight compaction of the surface soil from trampling. However, infiltration and percolation were moderately rapid, even under the grazed condition. Therefore, effects of grazing in relation to water intake or runoff would seem to be of minor importance on these sandy and level soils. Influences on soil aeration were not measured.

FOREST DISEASE RESEARCH[1/]

Littleleaf Disease of Pine

Much experimental evidence indicates that the littleleaf disease of shortleaf pine results mainly from nitrogen deficiency of the trees following the destruction of fine roots by Phytophthora cinnamomi in heavy soils. Plots containing littleleaf trees, that have been treated with either 3 or 4 applications of nitrogenous fertilizers over a period of 10 to 12 years continue to hold their own or improve, while those that have received other amendments, but very little or no nitrogen, have continued to decline.

Emphasis during 1953 has been put on the selection and propagation of shortleaf pines apparently resistant to littleleaf. Some crossing and inbreeding was done among eight such trees, yielding a small quantity of seed. Scions from these pollinated trees were also grafted on 2-year stocks and later set out to provide future breeding material and a seed orchard. In three States, three 2-acre areas from which littleleaf trees had been removed were planted with 12 geographic lines of shortleaf pine to compare their littleleaf resistance.

1/ Report of the Division of Forest Disease Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, in cooperation with the Southeastern Forest Experiment Station.

Comprehensive analyses on soil-nutrient relations, oxidation-reduction potential, and other soil factors not previously studied in relation to littleleaf have been under way. A 5-year shortleaf study involving artifically induced drought has provided strong evidence that some littleleaf-like symptoms can result from low soil moisture, but the symptom picture as a whole is different from littleleaf.

Oak Wilt

Aerial and ground surveys in 1953 brought the total counties where oak wilt has been found in the Southeast (table 9) to the following: Virginia 5, compared with 1 in 1952; Kentucky 4, compared with 3; Tennessee 8 versus 6; and no change in the other States. Good progress toward the removal of diseased trees has been accomplsihed in all of the southeastern States where oak wilt occurs, except in Tennessee. Local spread had taken place since 1952 in the case of 6 out of 16 areas observed.

Table 9.--Known distribution of oak wilt in southern Appalachian area up to September 1953

State	Counties with wilt	Infection centers found		
		1951	1952	1953
	Number	Number	Number	Number
Kentucky	4	1	1	4
North Carolina	3	10	6	7
Tennessee	8	13	6	30
Virginia	5	1	0	11

Spraying felled, unbarked, oak-wilt trees with a BHC-DDT-Penta mixture greatly reduced but did not eliminate fungus-mat-inhabiting insects on diseased trees. Five of the 29 wilting trees studied in 1953 developed fruiting mats of the fungus in the fall. The mats totaled 5-1/2 square feet of fruiting surface, from which 611 insects, mostly Nitidulid beetles, were collected. These beetles have been proven by others to be capable of inoculating healthy trees through wounds. Current studies in which Nitidulids were released 100 and 500 feet from down trees with oak wilt mats have shown some of these beetles to be attracted to the mats over both distances.

Studies during 1953 also showed that infection can originate in the upper branches of large trees.

Nursery Diseases

Visits were made to 4 Georgia nurseries at 3-week intervals during the growing season and also occasionally to other southeastern nurseries. Root rot, possibly of nematode origin, was common and studies were begun to obtain a satisfactory treatment. Nutritional problems were of major importance. Nitrogen deficiencies were corrected by spraying with urea at 50 pounds per acre. Iron deficiencies were corrected by iron chelate sprays at 20 pounds per acre. Phomopsis blight of Arizona cypress and redcedar was severe and studies were begun on sprays and seed treatments. Defects in watering procedures at some nurseries were turned up and measures were taken to correct them.

Mimosa Wilt

Two chemicals, Vancide 51 and Dithane D-14, gave 2-month-old mimosa seedlings some protection against the wilt disease in 1952 greenhouse tests. Additional greenhouse tests in 1953 indicated that these chemicals and a mixture of Puratized Agricultural Spray and ferbam are worth further study, as they reduced the incidence of wilt among seedlings. Vancide and Dithane were also applied in the field to soil around sapling mimosas that were later inoculated artifically--with inconclusive results.

Loblolly Pine Spot Die-Out

A survey was conducted in South Carolina to determine the nature and extent of many failures in 10- to 15-year-old loblolly plantations on federal, state, and private lands. Reports as early as 1948 suggested heavy mortality in certain plantings following an initial period of satisfactory establishment and growth. The dying of patches from 1/10 to 25 acres in extent was found to be common on certain sites and soil conditions in many plantations established in central South Carolina. Most of this decline and mortality has taken place in the last 3 years. Preliminary field observations indicate that mortality is greatest on flats or slight slopes and on soils with poorly drained subsoils possessing little or no topsoil. These observations also suggest that limited returns can be expected from a considerable acreage of loblolly plantations made in the past 15 years. Increasing numbers of such rapid loblolly failures are being reported and studied.

Virginia Pine Rust

This newly described rust (*Peridermium appalachianum*), discovered in 1948 (fig. 15), is now known in 15 counties in Virginia, Kentucky, North Carolina, and Tennessee. While observers report it to be increasing, and it is a killing disease, it is not yet an economic factor. Life history studies in 1953 involved making aeciospore inoculations on Virginia, shortleaf, and loblolly pine to determine whether the rust is autoecious, and something about its host relations. Later in the season a *Cronartium* was found on the leaves of the uncommon shrub *Buckleya distichophylla*, and inoculation attempts were made on the above 3 pine species, using germinating teliospores of the *Buckleya* rust. Two years will be required to evaluate these results.

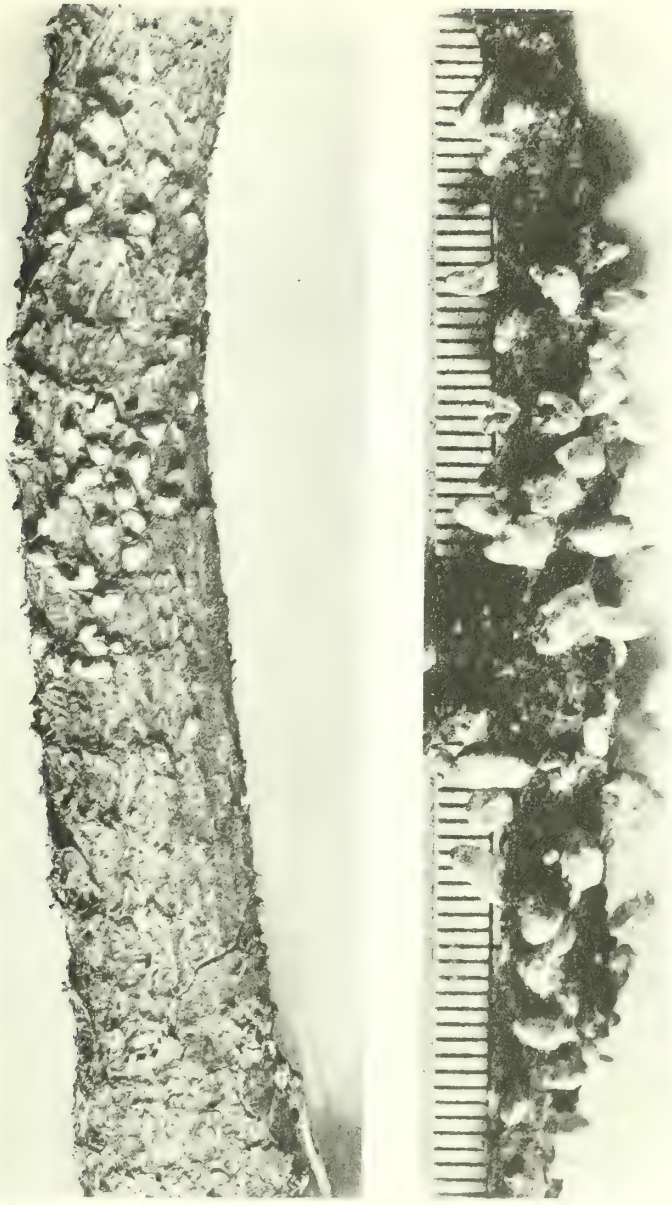

Figure 15.--Peridermium appalachianum, a recently discovered stem rust on Virginia pine. In appearance and manner of attack it resembles blister rust on white pine. At left, an infected branch, showing aecial blisters. At right, close-up of blister stage, with scale in millimeters.

Fomes Annosus Root Rot on Slash Pine

Although Fomes annosus is known to cause serious root and butt rots in many coniferous species in the United States and abroad, no cases of important damage to the southern pines were reported until 1953. Recently two pole-sized slash pine plantations--one in Georgia and one in South Carolina--have been found to have severe root rot leading to breaking over, and to some killing of trees. These examples of F. annosus aggressiveness in pole-sized slash pine plantations must be watched with care, especially since thinning tends to increase annosus damage. This development, plus the loblolly spot die-out situation, shows that plantations cannot be fully evaluated until they reach minimum merchantable size.

Other Pathology Problems

A large Chinese chestnut plantation was established at Bent Creek, comparing five of the best available strains, in randomized-block design, on two sites.

In a service project to the Navy, 300 wooden boats of 14 different types were examined for rot. Some came from active and inactive ships, and some were stored ashore. A report was submitted, giving suggestions for considerably reducing decay in such boats. Supervision of dip and brush preservative treatments was also provided several yards, and special studies were conducted on mine sweepers and on methods of dehumidification.

The pine leaf blight caused by Hypoderma lethale was effectively controlled by spraying with ferbam weekly from May 29 until August 14. Fewer sprays may also provide control.

In 1953, 299 disease inquiries were handled at Asheville, not counting the oak wilt survey. This compares with 143 in 1950, and 99 in 1947. Handling inquiries has become a major function.

Plans

Plans for 1954 include the following: selection and breeding for littleleaf resistance, and completion of the work on soil, soil oxygen, and littleleaf incidence; the fruiting habits of the oak wilt fungus and their relation to control; further surveys for oak wilt and supervision of control work; a broad attack on the major tree nursery diseases in Georgia and Florida; further inquiry into spot die-out of loblolly and Fomes annosus attack of slash pine; further testing of the possible hosts of the new Virginia pine rust; follow-up on sugar maple sapstreak; maintenance of a large number of plots in connection with littleleaf, blight-resistant chestnuts, mimosa wilt, and oak decay; and continued service to the Navy on decay in wooden boats.

FOREST INSECT RESEARCH[2/]

Forest insect activity in the Southeast has increased considerably during the past few years. Previous to 1950, foresters in this area reported few serious forest insect losses for a decade or more. Commencing in 1950, attacks by such insects as the black turpentine beetle, southern pine beetle, and Ips engraver beetles have increased and killed millions of feet of timber; defoliation by such insects as cankerworms, forest tent caterpillar, variable oak leaf caterpillar and pine sawflies stripped foliage from hundreds of thousands of acres of forests, causing growth loss and greater susceptibility to attack by secondary insects. Sucking insects such as Pineus pinifoliae, scales, and aphids became prevalent and caused serious injury. This increased activity by insects occurred during a period

2/ Report of the Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine, in cooperation with the Southeastern Forest Experiment Station.

of intensification of regional forestry practices and when forest insect survey activities were being initiated under provisions of the Forest Pest Act.

The need for protecting forests from insects is shown by the growing list of private, state, and federal agencies which have requested assistance on methods of preventing or reducing losses caused by insect attack on trees, logs, pulpwood and wood products. At the present time at least two private companies in the region have streamlined their woods practices so that they can salvage single, insect-attacked trees. There is no doubt that increased utilization of insect-killed material will continue.

Southern Pine Beetle

Reports that the southern pine beetle, Dendroctonus frontalis, was killing trees on the Chattahoochee National Forest in December 1952 were investigated. Surveys by aerial and ground methods indicated that 60 acres containing about 300 M feet had been killed by the southern pine beetle in 40 scattered locations. Investigations in 1953 indicated that the infestation was subsiding.

In August 1953 an increase in activity of the beetle was noted throughout western North Carolina and eastern Tennessee. This fact was called to the attention of forest owners in the area. Aerial and ground surveys demonstrated that kills were doubling with each generation of beetles. Ground surveys in the Tennessee portion of the Great Smoky Mountains National Park indicated that 750 trees were infested in Cades Cove. An additional 900 trees were estimated infested in the Park in North Carolina, on the Cherokee Indian Reservation, and on the Blue Ridge Parkway. In most locations the infestations occurred on very rocky, steep slopes, thereby lessening the possibilities of salvage.

Infestations of this beetle were also located on the French Broad and Catawba districts of the North Carolina National Forest. Aerial and ground surveys indicated that 1,500 pines were infested on the French Broad District early in September and that 6,000 were infested in the Catawba area. A recommendation was made on September 11 that these infestations be controlled as soon as possible.

Ground and aerial surveys in December indicated that individual beetle kills in the mountain region varied from a few trees up to 25 acres. At the end of the year it was estimated that a total of over 1,000 acres had been killed in patches which were over 1/2 acre in size. There was an aggregate of several hundred additional acres in kills of less than 1/2 acre.

Black Turpentine Beetle

During the years 1950-52 the black turpentine beetle, Dendroctonus terebrans, and Ips engraver beetles increased to epidemic proportions in northeast Florida and killed an estimated 25,000 M feet of pine. Aerial and ground surveys in the fall of 1952 and spring of 1953 in cooperation with the state of Florida indicated that stumps and trees infested last fall

showed less beetle emergence this spring because of competition by wood borers, termites, molds and fungi. Our surveys indicated that beetle populations were rapidly returning to endemic conditions and that special control measures beyond salvage were not justified.

This beetle has continued to be a serious problem on the Osceola National Forest since 1950, when it became active and began killing naval stores timber located in ponds, which were exceptionally dry at that time. Salvage of infested timber did not control the beetle, and appeared to aggravate the infestation. Salvage sales in 1950 totalled 827 M feet. During 1951, salvage sales amounted to 1,463 M feet. Efforts to control the beetle through use of penetrating toxic oil sprays containing 0.5 percent gamma benzene hexachloride commenced in December 1951. Losses to April 1952 exceeded 25 percent of the timber being turpentined and six crops (10,000 faces each) were lost. Salvage sales continued in 1952, during which period 7,392 M feet of pine was marked and sold. Up to January 31, 1953, 65,000 stumps and 6,500 seed trees had been sprayed. During 1953 about 10,000 M feet of pine is expected to be sold. Control measures are continuing on the Osceola National Forest. These measures at present consist of spraying seed trees with 0.5 percent gamma benzene hexachloride in fuel oil. Stumps are being peeled and the root collar sprayed with the 0.5 percent gamma BHC plus one-third pound of ethylene dibromide per gallon of fuel oil.

Ips Engraver Beetles

Drought conditions continued to prevail in the Southeast throughout most of 1953. Such conditions appear to favor the build-up of serious bark beetle populations. Ips bark beetles generally attack scattered trees throughout the stand, and damage does not appear to be serious. The damage is, therefore, not reported and no record is made of it. In the aggregate, however, the losses caused by Ips bark beetles are extremely serious as interpreted from information collected by the Division of Forest Economics, Southeastern Forest Experiment Station. Of over 212,000 M feet which were estimated to have been killed annually by insects in the Southeast (including Tennessee and Kentucky) during the past 3 years, about 90 percent or over 190,000 M feet with a stumpage value of over $4,750,000 was estimated to have been killed by Ips beetles.

Hickory Bark Beetle

Hickories throughout central North Carolina from Shelby to High Point were attacked and killed by the hickory bark beetle, Scolytus quadrispinosus. Killing of trees was especially common during the fall months when trees were observed dying in considerable numbers in farmers' woodlots and around homesites. Drought conditions, generally characteristic at the time when attacks by this beetle occur, were prevalent throughout the area of beetle activity.

Fall Cankerworm

An aerial survey of 2,000,000 acres of hardwood forests in the Southern Appalachian Mountains was made in May 1953. This survey located 63 areas of defoliation by the fall cankerworm, Alsophila pometaria. The comparative areas of defoliation since the infestation began 2 years ago indicate that defoliation increased from 15,000 acres in 1952 to over 120,000 acres in 1953.

Of the latter amount, 29,495 acres were heavily defoliated. The area heavily defoliated in 1953 was eight times greater than the previous year. This increase closely corresponded with an increase in the number of egg masses deposited.

The principal natural controls observed in 1953 were a late frost on April 26, which killed 21 percent of the potential larval population; a decrease in viability of the eggs from 80 percent in 1952 to 51 percent in 1953; and action of predatory Calasoma beetles and pentatomid bugs feeding on the larvae. Natural factors were not effective in controlling the 1953 infestation.

Two years of defoliation has not killed the trees. However, defoliation has weakened them and resulted in trees being only partially refoliated with undersized leaves. Control operations have been recommended for the aerial spraying of 500 acres of Mount Pisgah with DDT.

Sawflies

A sawfly, Neodiprion dyari, was reported as causing defoliation in Marion County, Florida, early in February. Another Neodiprion defoliated scattered pond pine in March on 23,000 acres in Berkeley County, South Carolina. Defoliation of 50 acres of pond pine in the South Carolina area was first noted about 1946. Since then this sawfly has reportedly spread over thousands of acres. Defoliation by the sawfly has apparently not been responsible for tree mortality, although the annual loss of needles has undoubtedly caused considerable growth loss. Limited observations to date indicate that dipterous and hymenopterous parasites are exerting a considerable degree of control. Another species, Neodiprion americanum, defoliated small areas of loblolly pine during the month of June from Virginia to Georgia. Early in October scattered defoliation by the red headed pine sawfly, Neodiprion lecontei, occurred on several hundred acres near Lake City and in Hillsboro County, Florida. Complete stripping of small groups of trees was noted throughout northeastern Florida on this latter date.

Variable Oak Leaf Caterpillar

The variable oak leaf caterpillar, Heterocampa manteo, was reported to have defoliated hundreds of thousands of acres of oak and hickory in central and western Tennessee. This species also caused stripping of oak on thousands of acres in western Kentucky around Kentucky Lake.

Nantucket Pine Moth

The Nantucket pine moth, Rhyacionia frustrana, and another species, R. rigidana, continued, as in previous years, to be serious pests of young pine throughout the Southeast from Virginia to Florida. Studies on the effect of tip moth attack on height growth and on control measures were initiated in 1953 at Union, South Carolina. In many areas, especially of loblolly pine, nearly every leader was attacked during the fall months.

Pales Weevil

The Pales weevil, Hylobius pales, and a closely related species, Pachylobius picivorous, are pests of considerable importance to pine reproduction in the Southeast, although they are not generally recognized as such. The adults of these weevils alone or in conjunction with those of cerambycid and buprestid larvae are able to kill pine reproduction by feeding on the bark of seedlings and girdling them. The greatest amount of injury occurred on and adjacent to areas which had been logged, beetle-killed, burned, or windthrown. Beetles are attracted to this type of material previous to oviposition and following emergence of adults from pine stumps where they breed. Plantings of pine within one year of logging are likely to suffer considerable mortality from attack by these pests. Killing of especially valuable planting stock at Union, South Carolina, by these beetles was prevented by the application of DDT spray to the seedlings.

White Grubs

White grubs, Phyllophaga spp., have been considered to be serious pests in forest tree nurseries in this area for some time but seldom have they been reported as serious pests of either natural or planted stock. A report of serious injury to planted stock on extensive areas at the Savannah River Project in South Carolina was investigated in October. White grubs were found to have caused serious injury to the roots of loblolly, slash, and longleaf pine seedlings planted early in 1953. Sampling of the injury over the 10,000 acres indicated that white grubs in combination with dry weather had caused mortality varying from 5 to 100 percent. There is little doubt that a mortality of several million seedlings occurred. Planting of this year's stock commenced on November 16. Plans were formulated to dip the roots of 10 million seedlings in an organic insecticide prior to planting and to conduct a screening test of several additional insecticides to determine their value in providing protection of the planting stock from grub injury.

PUBLICATIONS

by

MEMBERS OF THE STAFF, INCLUDING COOPERATORS

Calendar Year 1953

ALDRICH, R. C.
Aerial photographs and the forest survey. The Cypress Knee. Univ. Ga., School Forestry 29: 46, 59, 60.

Use and limitations of aerial photographs on extensive forest surveys.

ALDRICH, R. C.
Accuracy of land-use classification and area estimates using aerial photographs. Jour. Forestry 51(1): 12-15. Jan.

An analysis of how accurately land use can be classified on aerial photographs and what intensity of ground checking is needed to achieve the accuracy required.

BARBER, J. C.
Tree planting at the Bent Creek Experimental Forest. Southeast. Forest Expt. Sta. Station Paper 27. 11pp. Aug.

A report on the survival and growth of experimental plantings, including the arboretum established in 1926.

BENNETT, F. A.
Topwood volume tables for slash and longleaf pine. Southeast. Forest Expt. Sta. Research Note No. 42. July.

Tables of cordwood volume in tops of sawlog trees are given for turpentined and round longleaf and slash pines in the upper Coastal Plain of Georgia.

BENNETT, F. A.
Site indexes of the soil series on the George Walton Experimental Forest. Southeast. Forest Expt. Sta. Research Note No. 34. May. Also, with title Drain sites best for slash pine, in Naval Stores Rev. 63(19): 22. Aug. 22.

Exploratory study of site index and soil series in south Georgia shows that poorly drained soils are better sites for slash pine. On identical soils, slash pine shows a higher site index than longleaf pine.

BOYCE, J. S., Jr.
Needle blights of pines in the Southeast. Arborist's News 18(10): 89-91. Oct.

Describes the symptoms and control of several common needle diseases of yellow pines in the Southeast.

BOYCE, J. S., Jr., and GARREN, K. H.
Compatibility types of the oak wilt fungus in 23 Appalachian trees. Phytopath. 43(11): 644-645. Nov.

Cultures from oak wilt trees made in 1952 showed that most trees are infected with only 1 of the 2 compatibility types of the fungus and thus cannot produce the sexual stage spores unless mating of the A-type and B-type takes place between trees. The study also established that infection can take place in the upper tree crown.

BURKS, G. F., TODD, A. S., Jr., and HAIR, D.
Trends in pulpwood supplies in the United States. The Paper Industry 35(9): 982-987. Dec.

Softwood timber in Alaska and the Rocky Mountains, as well as hardwoods, cull trees, and sawmill residues in all regions, can provide raw material for continued expansion of the pulp and paper industry.

CAMPBELL, R. A.
Logging methods and costs in the Southern Appalachians. Southeast. Forest Expt. Sta. Station Paper No. 30. 29pp. Oct.

A report on a comprehensive study of the variables affecting logging costs in typical mountain topography and a summary of costs for typical operations.

CAMPBELL, R. S., and SHEPHERD, W. O.
Forest grazing in the Southeastern United States. Sixth International Grassland Congress Proc. pp. 1550-1555. 1952, pub. 1953.

General situation review; major forest range types and species, grazing capacity and forage values, season of use, problems and opportunities.

CAMPBELL, W. A., and COPELAND, O. L., Jr.
Littleleaf disease. Amer. Forests 59(6): 23, 51. June.

A brief general account of the symptoms, cause, distribution, and soil relations of littleleaf.

CAMPBELL, W. A., COPELAND, O. L., Jr., and HEPTING, G. H.
Littleleaf in pines in the Southeast. In Plant Diseases, Yearbook of Agriculture 1953, pp. 855-857. U. S. Dept. Agr., Washington, D. C.

A brief general account of the symptoms, cause, distribution, and soil relations of littleleaf, with suggestions for reducing losses.

CAMPBELL, W. A., COPELAND, O. L., Jr., and HEPTING, G. H.
Managing shortleaf pine in littleleaf disease areas. Southeast. Forest Expt. Sta. Station Paper No. 25. June.

A resume of that part of the results of 15 years of research on littleleaf that deals with field behavior, site, and soil factors, salvage, stand management, and other aspects of practical forest management in littleleaf areas.

CLEMENTS, R. W.
The bark hack. Naval Stores Rev. 62(42): 12-13, 27-28. Jan. 17. Also, with title Training the chipper to use the bark hack, in AT-FA Jour. 15(5): 12-13, 15. Feb.

Gum producers converting to bark chipping should train woods labor in the proper use of a bark hack. Training methods are discussed.

CLEMENTS, R. W.
Correct use of the spray gun. Naval Stores Rev. 62(51): 16-17. March 21. Also, with title Correct use of the acid spray gun, AT-FA Jour. 15(8): 8-9, 11. May.

Good acid treatment requires correct amount of acid and correct placement on the streak. Discussion tells proper methods for obtaining both.

CLEMENTS, R. W.
How to install spiral gutters with double headed nails. AT-FA Jour. 16(2): 4. Nov. Also, with title How to install spiral gutters, in Naval Stores Rev. 63(21): 14, 15. Oct. 17.

Spiral gutters attached with double-headed nails increase the yield of gum, are easily installed and removed, and do not damage the tree. Instructions for installation include photographs.

COOPER, R. W.
Prescribed burning to regenerate sand pine. Southeast. Forest Expt. Sta. Research Note No. 22. Jan. Also in South. Lumberman 186(2331): 50. May 15.

Early response to prescribed burning indicates that more information is needed on the time of year to burn, on the interval between cutting and burning, and on the number of seed trees.

COOPER, R. W.
Keeping sand pine woodlands in production. South. Lumberman 187(2345) 154-155. Dec. 15.

To keep sand pine stands in production, clearcutting in the fall or early winter is recommended, and should be followed by tractor skidding to prepare a suitable seedbed.

COOPER, R. W., and SCHOPMEYER, C. S.
Viability of sand pine seed. Southeast. Forest Expt. Sta. Research Note No. 23. Jan.

Viability of sand pine seed retained in cones decreases with age of cone.

CRUIKSHANK, J. W.
Forest survey and timber resources review. Conserv. Congress Proc., N. C. Board of Conserv. and Devlpmt. 1: 103-106. 1952, pub. 1953.

Description of national forest survey, methods used in North Carolina and data obtained. Also brief description of the several phases of The Timber Resource Review of the Forest Service.

CRUIKSHANK, J. W.
Labor requirements in forestry and forest industry. In Research in the Economics of Forestry, pp. 121-127. Charles Lathrop Pack Forestry Foundation, Washington, D. C.

Procedure to be used in determining the labor required for specific forest management and timber harvesting operations.

DEMMON, E. L.
Georgia's forest survey shows new trends. The Paper Industry 35(2): 188-190. May.

Changes in the supply and quality of the timber resource are revealed. Recommendations are made for needed changes in timber utilization, forest practice, and forest research program.

DEMMON, E. L.
Forest research and its relation to the wood-using industries in the Southeast. Jour. Forest Prod. Res. Soc. 3(2): 10-12, 85. June.

Highlights of research at the Southeastern Forest Experiment Station and its eight centers, with particular emphasis on utilization. Finding new uses and markets for low-grade hardwoods, developing and growing better trees, expanding research in anticipation of demands by wood chemical industry.

DEMMON, E. L.
Trends in southern hardwood forestry. South. Lumberman 187(2345): 174-177. Dec. 15.

Interest in hardwood management, uses, markets, and research is rising throughout the region.

DILS, R. E.
Influence of forest cutting and mountain farming on some vegetation, surface soil and surface runoff characteristics. Southeast. Forest Expt. Sta. Station Paper No. 24. 55pp. June.

Reports a watershed experiment where the original hardwood forest was cleared and the land used as a mountain farm.

DOOLITTLE, W. T.
Growth and survival of hybrid poplars. South. Lumberman 187(2345): 178-179. Dec. 15.

Experimental plantings of 12 hybrid poplar clones set out in 1935 show that juvenile growth of certain clones compares favorably with rapid-growing native species.

DORMAN, K. W.
A taxonomic study of slash pine. (Abs.) Assoc. South. Agr. Workers Proc. 50: 116-117.

Slash pine, one of the most valuable southern pines, is a distinct species from Caribbean pine, with which it has usually been united. The related pine of southern Florida is now recognized as a botanical variety.

DORMAN, K. W., BAUER, E., and GREENE, J. T.
Tree improvement makes a step ahead. South. Lumberman 187(2345): 170-171. Dec. 15.

A description of the history and progress of the tree improvement program at the Ida Cason Callaway Foundation, Hamilton, Ga.

ENGLERTH, G. H.
A key to the genera of the gilled fungi. U. S. Dept. Agr., Bur. Plant Indus., Soils, and Agr. Engin., Div. Forest Path. leaflet.

Contains a descriptive key in chart form for the identification of the more common genera of mushrooms.

GREENE, G. E.
Soil temperatures in the South Carolina Piedmont. Southeast. Forest Expt. Sta. Station Paper No. 29. 16pp. Sept.

Measurements are discussed for the upper 6 feet of soil under four cover conditions: 40 and 11-year-old pine, broomsedge, and bare soil.

GRUSCHOW, G. F.
Better woods + $10 a year. The Progressive Farmer 68(1): 81. Jan.

An average flatwoods farm woodland under management yields a gross financial return in 5 years of $62.00 per acre for products at the roadside.

HALLS, L. K.
Improved cattle forage under southern pines. South. Lumberman 187(2345): 218, 220. Dec. 15.

Productivity of introduced forage species in relation to density of the pine overstory. Discussion of promising forage species for range improvement and fire hazard reduction.

HAINES, W. H. B.
86 percent of tops and 54 percent of slabs and edgings unused in central Piedmont of South Carolina. Southeast. Forest Expt. Sta. Research Note No. 35. May.

The quantity and use of logging and sawmill waste.

HAINES, W. H. B.
62 percent of pine lumber is cut from 10-inch or smaller logs in the central Piedmont of South Carolina. Southeast. Forest Expt. Sta. Research Note No. 36. May. Also, with title Sixty-two percent of lumber cut from 10-inch or smaller logs in S. C., in The Unit 49: 11. Sept.

Lumber output by log and tree size.

HAWLEY, N. R.
25-year-old stand shows unusual yield. Forest Farmer 12(7): 10-11. April.

A slash pine plantation in south Georgia returns $7.71 per acre per year during the first 25 years of its life.

HAWLEY, N. R.
Rapid growth of planted slash pine in the middle Coastal Plain of Georgia. Southeast. Forest Expt. Sta. Research Note No. 32. May. Also, with title Growth of planted slash pine in Georgia, in South. Lumberman 187(2334): 60. July 1. Also, with title Rapid growth of planted slash pine, in The Unit 49: 8. Sept.

Over the 18 years since planting, the Stephens plantation near Cordele, Ga., has averaged 1.74 cords per acre per year. Sawtimber production over the same period is 370 board feet per year.

HAWLEY, N. R.
Merchantable height greater after improvement cut in pilot-plant management test. Southeast. Forest Expt. Sta. Research Note No. 33. May.

The first improvement cut in young longleaf-slash pine sawtimber increased average merchantable heights by 2-1/2 feet, and volume of average trees by 10 percent.

HEPTING, G. H.
Diseases of forest trees in Virginia. Va. Forests 8(5): 8-10. Sept.-Oct.

Major forest tree diseases in Virginia.

HEPTING, G. H.
Forest tree diseases in North Carolina. Conserv. Congress Proc., N. C. Board of Conserv. and Devlpmt. 1:89-92. Nov. 1952, pub. 1953.

A digest of the major forest diseases in North Carolina, the losses they cause, present status, and progress being made toward their solution. The diseases featured are chestnut blight, oak wilt, littleleaf, fusiform rust, brown spot, and the cull problem.

HOOVER, M. D.
Interception of rainfall in a young loblolly pine plantation. Southeast. Forest Expt. Sta. Station Paper 21. 13pp. Jan.

In a two-year study 12 and 16 percent of the annual rainfall was intercepted by the tree canopies and did not reach the ground. Of the amount reaching the ground one-fifth was measured as water flowing down the tree trunks.

HOOVER, M. D., OLSON, D. F., Jr., and GREENE, G. E.
Soil moisture under a young loblolly pine plantation. Soil Sci. Soc. Proc. 17(2): 147-150. April.

In a 2-year study using fibreglas electrodes it was found that pine roots depleted soil moisture to a depth of at least 5-1/2 feet, bringing it to wilting point in August 1951. In March 1952 when at field capacity the same soil depth had stored nearly 10 inches of rain as soil moisture.

HURSH, C. R.
Forest management in East Africa in relation to local climate, water and soil resources. East African Agr. and Forestry Res. Organ. Ann. Rpt. 1952, pp 26-35.

Good forestry is the key to improving and conserving the local climate, water, and soil resources of East Africa.

HURSH, C. R., and PEREIRA, H. C.
Field moisture balance in the Shimba Hills, Kenya. East African Agr. Jour. 18(4): 1-7. April.

For the equatorial coastal conditions studied, a high tropical forest was considered to be more favorable to ground-water storage than the adjacent, annually-burned grass vegetation.

JENKINS, A., MILLER, J. H., and HEPTING, G. H.
Spot anthracnose and other leaf and petal spots of flowering dogwood. The Natl. Hort. Mag. 32: 57-69. April.

Describes several common dogwood blights and means of control. Well illustrated. The first such treatment given to dogwood diseases.

KEETCH, J. J., and GLADSTONE, M. C.
1952 forest fires and fire danger in Maine. Southeast. Forest Expt. Sta. 70pp. July.

Tables and graphs analyzing forest fires and fire danger.

KEETCH, J. J., and GLADSTONE, M. C.
1952 forest fires and fire danger in New York. Southeast. Forest Expt. Sta. 32pp. July.

Tables and graphs analyzing forest fires and fire danger.

KEETCH, J. J., and GLADSTONE, M. C.
1952 forest fires and fire danger in Vermont. Southeast. Forest Expt. Sta. 20pp. July.

Tables and graphs analyzing forest fires and fire danger.

KEETCH, J. J., and GLADSTONE, M. C.
1952 forest fires and fire danger in Pennsylvania. Southeast. Forest Expt. Sta. 78pp. Aug.

Tables and graphs analyzing forest fires and fire danger.

KEETCH, J. J., and GLADSTONE, M. C.
1952 forest fires and fire danger in New Hampshire. Southeast. Forest Expt. Sta. 29pp. Aug.

Tables and graphs analyzing forest fires and fire danger.

KEETCH, J. J., and GLADSTONE, M. C.
1952 forest fires and fire danger in Connecticut. Southeast. Forest Expt. Sta. 22pp. Sept.

Tables and graphs analyzing forest fires and fire danger.

KEETCH, J. J., and GLADSTONE, M. C.
1952 forest fires and fire danger in New Jersey. Southeast. Forest Expt. Sta. 29pp. Sept.

Tables and graphs analyzing forest fires and fire danger.

KEETCH, J. J., and GLADSTONE, M. C.
1952 forest fires and fire danger in Maryland. Southeast. Forest Expt. Sta. 34pp. Oct.

Tables and graphs analyzing forest fires and fire danger.

KEETCH, J. J., and GLADSTONE, M. C.
1952 forest fires and fire danger in Kentucky. Southeast. Forest Expt. Sta. 42pp. Nov.

Tables and graphs analyzing forest fires and fire danger.

KEETCH, J. J., and GLADSTONE, M. C.
1952 forest fires and fire danger in Massachusetts. Southeast. Forest Expt. Sta. 36pp. Dec.

Tables and graphs analyzing forest fires and fire danger.

KEETCH, J. J., and GLADSTONE, M. C.
1952 forest fires and fire danger in Virginia. Southeast. Forest Expt. Sta. 61pp. Dec.

Tables and graphs analyzing forest fires and fire danger.

KEETCH, J. J., and GLADSTONE, M. C.
1952 forest fires and fire danger in West Virginia. Southeast. Forest Expt. Sta. 49pp. Dec.

Tables and graphs analyzing forest fires and fire danger.

LARSON, P. R., and CLEMENTS, R. W. More gum without broadaxe incisions. Naval Stores Rev. 63(20): 12, 13. Sept. 19. Also in AT-FA Jour. 16(1): 8, 9. Oct.

Gum yields of longleaf pine have been increased by as much as 60 barrels per crop merely by nailing-on gutters and aprons instead of inserting tins in broadaxe incisions.

LARSON, P. R.
Early season streaks unprofitable. Naval Stores Rev. 63(19): 20, 21. Aug. 22. Also in AT-FA Jour. 16(1): 15. Oct.

Yield of individual streaks weighed for nine different studies on slash pine over a 5-year period show that low profit in marginal timber may be caused by low yields of the early and late season streaks.

LARSON, P. R.

Turpentine trees remain healthy after nine years of acid work. South. Lumberman 187(2345): 214, 216. Dec. 15. Also in Naval Stores Rev. 63(23): 12, 13. Dec. Also in AT-FA Jour. 16(3): 4, 5. Dec.

Gum yields of both untreated, wood-chipped and acid-treated, bark chipped slash pine showed no appreciable decline during 9 years of work.

LINDENMUTH, A. W., Jr.

How dry were southern Appalachian forests in the fall of 1952. Southeast. Forest Expt. Sta. Research Note No. 24. Jan.

An analysis of rainfall, cumulative danger index, lower litter moisture, and burning index records indicated extremely severe burning conditions during the period October 17 - November 8.

LINDENMUTH, A. W., Jr., and KEETCH, J. J.

Fire prevention efforts pay off in the Northeast. Fire Control Notes 14(1): 14-16. Jan.

The frequency of forest fires in 13 Northeastern States dropped about one-half during the period 1943-1950. The method of analysis takes out the effect of weather so the reduction can be attributed largely to more effective prevention efforts.

LINDENMUTH, A. W., Jr., and KEETCH, J. J.

1951 forest fires and fire danger in New York. Southeast. Forest Expt. Sta. 34pp. Feb.

Tables and graphs analyzing forest fire and fire danger.

LINDENMUTH, A. W., Jr., and KEETCH, J. J.

1952 forest fires and fire danger in Rhode Island. Southeast. Forest Expt. Sta. 17pp. June.

Tables and graphs analyzing forest fire and fire danger.

LINDENMUTH, A. W., Jr., and KEETCH, J. J.

Fire frequency as a measure of fire prevention accomplishments. Southeast. Forest Expt. Sta. Research Note No. 37. July.

1951 fire occurrence in 13 Northeastern States was lower than might reasonably have been expected when the severity of the weather is taken into consideration.

LOTTI, T.

Good seed trees pay off. South. Lumberman 187(2336): 43-44. Aug. 1.

Leaving 4 to 12 seed trees per acre on a 200-acre logging chance in coastal loblolly pine resulted in 85 to 90 percent milacre stocking 3 years after logging.

MCCLAY, T. A.
Estimating board widths obtainable from pine trees of different diameters. Southeast. Forest Expt. Sta. Research Note No. 25. Jan.

Offers a means by which percentage of 1-inch boards of 4- to 12-inch widths in trees ranging from 10 to 24 inches d.b.h. may be estimated from a timber cruise. Quoted percentages are substantiated by ten actual operations.

MCCLAY, T. A.
Estimating time requirements for tree poisoning with Ammate. Southeast. Forest Expt. Sta. Research Note No. 27. Jan. Also in Jour. Forestry 51(12): 909. Dec.

The time required to poison inferior dominant hardwoods is shown to be correlated with the number of stems to be treated and the sum of their diameters.

MCCLAY, T. A.
Relation of tree size to production rates when cutting pine pulpwood with a chain saw. Southeast. Forest Expt. Sta. Research Note No. 28. Jan.

The effect of tree size upon felling and bucking time for pine pulpwood is shown by comparing the time cost for a 10-inch, 7-bolt tree with all other sizes. Man-hour costs are also given by tree diameter classes.

MCCLAY, T. A.
The relation of growth to severity and season of pruning open-grown loblolly pine. Jour. Forestry 51(4): 287-288. April.

Pruning to one-half and two-thirds total height in summer and winter showed that diameter growth is significantly reduced by increasing severity of pruning, but is not affected by season of treatment. Height growth was not affected by either severity or season.

MCCLAY, T. A.
Growth, mortality, and regeneration after cutting in loblolly pine pulpwood stands. Southeast. Forest Expt. Sta. Station Paper No. 28. 15pp. Sept.

Heavy thinning from below in 25- to 30-year-old loblolly pine produced greater returns in the decade after cutting than moderate thinning from below, seed-tree, shelterwood, or diameter-limit cutting.

MCCORMACK, J. F.
Forest statistics for central Georgia, 1952. Southeast. Forest Expt. Sta. Forest Survey Release No. 40. 44pp. July.

Forest area, timber volume, growth and drain statistics and trends in timber volume.

MCCORMACK, J. F.

D.b.h. in relation to stump diameter at various heights for southern yellow pines and hardwoods. Southeast. Forest Expt. Sta. Research Note No. 43. July.

A table showing tree diameter outside bark at 4.5 feet above ground in relation to stump diameter at various heights.

MCCORMACK, J. F.

Forest statistics for the southern Coastal Plain of North Carolina, 1952. Southeast. Forest Expt. Sta. Forest Survey Release No. 41. 45pp. Sept.

Forest area, timber volume, growth, and drain statistics and trends in timber volume.

MCCULLEY, R. D.

Controlling seed production and seed utilization in loblolly pine. (Abs.) Assoc. South. Agr. Workers Proc. 50: 117-118.

Suggested management practice to insure natural reproduction includes short cutting cycles, proper timing of the cut to coincide with good seed years, stimulation of seed production by preharvest release, and seedbed preparation.

MCCULLEY, R. D.

The case for even-aged management of southern pine. Jour. Forestry 51(2): 88-90. Feb.

A defense of even-aged management, presented at the symposium on all-aged vs. even-aged management of southern pines during the 1951 SAF Meeting at Biloxi, Mississippi.

MCCULLEY, R. D.

Estimating growing space liberated by the removal of residual hardwoods. Southeast. Forest Expt. Sta. Research Note No. 31. May. Also in Naval Stores Rev. 63(12): 20. June 20.

An estimate of the area shaded by residual hardwoods can be obtained by multiplying the basal areas in hardwoods by 1.4.

MCCULLEY, R. D.

Gunning for loblolly pine cones. Southeast. Forest Expt. Sta., Research Note No. 40. July.

A .22 rifle, equipped with telescopic sight, proves effective tool for collecting pine cones on trees which cannot be cut or climbed.

MCCULLEY, R. D.

Natural regeneration of loblolly pine in the southeastern Coastal Plain. Southeast. Forest Expt. Sta. Station Paper No. 26. 14pp. Aug.

A review of recent research in natural regeneration of loblolly pine, and recommendations for applied management.

MCCULLEY, R. D.
The seed-tree system: a summary of recent research in loblolly pine. The South. Lumber Jour. 57(8): 20, 22, 90-91. Aug.

A summary of recent research on seeding characteristics, cone-crop forecasts, seed-crop stimulation, seedbed preparation, and their coordination for the practical management of loblolly pine.

MERGEN, F.
Leaf pigments in five conifers in relation to apparent light tolerance. (Abs.) Assoc. South. Agr. Workers Proc. 50: 171.

This paper reports results of a study which was carried out to find a possible relationship between the amount of chlorophyll and other pigments in the needles and the apparent light tolerance of some conifers.

MERGEN, F.
Gum yield in longleaf pine inherited. Naval Stores Rev. 62(47): 18-19. Feb. 21. Also, with title Gum yields in longleaf pine are inherited, Southeast. Forest Expt. Sta. Research Note No. 29. Jan. Also in AT-FA Jour. 15(5): 14, 17. Feb.

First evidence that gum-yielding capacity is inherited is obtained from 17-year-old progeny test.

MERGEN, F.
The story of some unique trees. South. Lumberman 186(2329): 72, 74. April 15.

For the first time in history, mature cones were collected from rooted slash pine cuttings. In addition to being a historical "first," it represents one step closer to the goal of developing high-yielding pines for naval stores.

MERGEN, F.
Selection and breeding of slash and longleaf pine at Lake City, Florida. (In English.) Zeitschrift für Forstgenetik und Forstpflanzenzüchtung 2(6): 126-129. Frankfurt, Germany. Also, with title Selection and breeding of longleaf pine, in Naval Stores Rev. 63(7): 12-14, 23-26. May 16.

Research in species improvement of longleaf and slash pine at the Lake City Research Center includes tree selection, vegetative propagation, and controlled breeding. Preliminary results are discussed.

MERGEN, F.
First mature cones collected from rooted slash pine cuttings. AT-FA Jour. 15(10): 8-9. July.

Beginning with the rooting of cuttings in 1943-44, this is the first recorded production of mature cones from rooted slash pine.

MERGEN, F.

Air-layering as a possible method to reproduce selected slash pine. Naval Stores Rev. 63(21): 19, 20. Oct. 17.

Long known to horticulturists as a method of reproducing cultivated plants, air-layering has been used successfully for the first time on slash pine.

MERGEN, F., and POMEROY, K. B.

Some practical suggestions for better slash pine seed. The South. Lumber Jour. 57(11): 88-89. Nov.

Organizations with extensive reforestation programs might improve seed quality in slash pine by improving selected natural stands of vigorous, even-aged, cone-bearing trees. Method of improvement and hints for seed collection are discussed.

NELSON, T. C.

Honeysuckle is a serious problem. Forest Farmer 12(11): 14-16. Aug. Also in Southeast. Forest Expt. Sta. Research Note No. 41. July.

Best hope for reducing honeysuckle invasion, common throughout the Piedmont, is the use of weed-killers. Degree of shade and time of year are probably more important than chemical concentration or dosage.

OSTRANDER, M. D., and ENGLERTH, G. H.

Hardwood log grading scale stick improved. Northeast. Forest Expt. Sta. Research Note No. 24. Sept.

Illustrates a hardwood log grading stick based on the Forest Service Standard Hardwood Log Grades. Describes how to use it.

OSTROM, C. E.

More and better trees: the activities of the Committee on Southern Forest Tree Improvement. South. Lumberman 186(2326): 35-36. March 1. Also, with title Accomplishments of the Committee on Southern Forest Tree Improvement, in Naval Stores Rev. 62(51): 14-15, 26-28. March 21. Also, with title Recent developments in the southern forest tree improvement program. (Abs.) Assoc. South. Agr. Workers Proc. 50: 115-116.

Discussion of the function, accomplishments, and plans of the Committee on Southern Forest Tree Improvement.

POMEROY, K. B.

Cooperative research--key to the future. Forest Farmer 12(5): 19, 38. Feb.

Selected examples of collective effort among federal, state, and industrial agencies demonstrates that cooperative research in Florida pays high dividends.

POMEROY, K. B.
Tree improvement--its potentialities. Forest Farmer 12(11) 8-9, 11. Aug. Also in The Unit 48: 25-27. July. Also in Paper Trade Jour. 137(6): 18-19. Aug. 7.

Preliminary results show that the value of forest trees can be increased by genetic control of inherited characteristics. Best returns in forest tree improvement will probably be achieved by combined efforts of silviculturists working with environmental factors and geneticists working with inherited factors.

POMEROY, K. B.
Forest research progress. Naval Stores Rev. Internatl. Yearbook, 1953: 77-80. Aug. 31.

Summary of the research program in naval stores, forest management, genetics, and protection at the Lake City Research Center.

POMEROY, K. B.
Research in tree improvement at Lake City. TAPPI 36(11): 147a-150a. Nov.

Forest managers who remove undesirable trees, leave only the best trees for regeneration, and plant seedlings from the best available local parentage can reap the benefits of eugenic forestry while waiting for the deferred benefits of controlled breeding.

POMEROY, K. B.
Better trees for tomorrow. Naval Stores Rev. 63(20): 19, 21-22. Sept. 19. Also in AT-FA Jour. 16(2): 18. Nov.

Propagation and controlled breeding, proven tools of the horticulturist and agronomist, are now being used in developing superior strains of longleaf and slash pine.

ROTH, E. R.
Sprout oak decay. Amer. Forests 59(1): 35, 43. Jan.

An account of the manner in which stump-sprout oaks become butt-rotted early from the parent stumps and from the cut stubs of companion sprouts. Sprouts arising at or near the ground line on parent stumps seldom contract stump rot, while sprouts arising more than an inch or two above ground line usually become decayed.

SCHOPMEYER, C. S.
A review of some physiological aspects of oleoresin flow from slash and longleaf pine. (Abs.) Assoc. South. Agr. Workers Proc. 50: 172.

Two theories are advanced to explain the mechanism of oleoresin transfer from epithelial cells into resin ducts.

SCHOPMEYER, C. S.

The characteristics of a high-gum-yielding tree. Naval Stores Rev. 63(12): 12-13. June 30. Also in AT-FA Jour. 15(10): 4. July. Also in Southeast. Forest Expt. Sta. Research Note No. 39. July.

The factors controlling gum flow in slash pine appear to be size of resin ducts exposed by chipping, number of ducts per square inch of fresh face, viscosity of gum, and exudation pressure. If these factors are inheritable, trees rating high on all four can be developed by controlled breeding.

SCHOPMEYER, C. S.

Removable gutters: key to better conservation of naval stores timber. South. Lumberman 187(2345): 112-115. Dec. 15.

By using special gutters attached with double-headed nails, jump-butting may be eliminated, with an estimated increase in stumpage value of over $400 per crop.

SHEPHERD, W. O.

Effects of burning and grazing flatwoods forest ranges. Southeat. Forest Expt. Sta. Research Note No. 30. May. Also, with title Effects of burning and grazing, in Naval Stores Rev. 63(12): 17, 20. June 20.

Summary of 7-year study of burning longleaf-slash pine forest range at intervals of 1, 2, and 3 years; ecological trends with and without grazing, chemical composition of forage, diet and weight gains of young cattle, fuel accumulation, tree reproduction. General effect of tree cover on understory vegetation. (Based on Ga. Coastal Plain Expt. Sta. Bul. 51 by Halls, et al.)

SHEPHERD, W. O., and DILLARD, E. U.

Best grazing rates for beef production on cane range. N. C. State Agr. Expt. Sta. Bul. 384. 23pp. Oct.

Results of a 3-year study of six intensities of summer grazing on highly productive range in eastern North Carolina; effects on cow and calf gains, range productivity, fire hazard. Maximum long-term benefits realized at 55-60 percent utilization of cane foliage.

SHEPHERD, W. O., SOUTHWELL, B. L., and STEVENSON, J. W.

Grazing longleaf-slash pine forests. U. S. Dept. Agr. Cir. 928. 31pp. Nov.

Results of a 5-year study of breeding herds on "wiregrass" range in southern Georgia; range use as influenced by burning; also range plants and forage quality, number and size of calves, factors limiting herd productivity, influences of fall and winter herd management practices.

SHIPMAN, R. D.
Poisoning small-diameter hardwoods with the Cornell tool. Southeast. Forest Expt. Sta. Research Note No. 38. July.

Eighteen months after treatment with Ammate applied with a Cornell tool, only one-quarter of the small hardwoods studied were still living. The least effective kill occurred with dogwood and hickory.

SMITH, W. R.
Utilization of wood waste. Conserv. Congress Proc., N. C. Board of Conserv. and Devlpmt. 1: 107-110. 1952, pub. 1953.

A description of the amount of wood residue available in North Carolina and some of its possible uses.

SMITH, W. R., MILLER, R. H. P., BROWN, O. A., and WELDON, N. W.
The development of an automatic wood-burning furnace for curing brightleaf tobacco. Southeast. Forest Expt. Sta. Station Paper No. 23. 41pp. April.

Describes the construction and operation of an automatic wood-burning furnace as developed after 8 years of experimental research. Fully illustrated.

SOUTHEASTERN Forest Experiment Station
Annual report for 1952. Southeast. Forest Expt. Sta. Station Paper No. 22. 42pp.

TODD, A. S., Jr.
Forest products marketing in an area. In Research in the Economics of Forestry, pp. 336-343. Charles Lathrop Pack Forestry Foundation, Washington, D. C.

Procedure to be used in making a study of the distribution of forest products in an area.

TODD, A. S., Jr.
Small sawmills as buyers of southern pine timber. Jour. Forestry 51(3): 169-172. March.

How small sawmill operators buy timber in the North Carolina Piedmont.

TODD, A. S., Jr.
Sawmill and logging residues in the South Carolina Piedmont: problems and methods of salvage. Southeast. Forest Expt. Sta. Station Paper No. 31. 32pp. Nov.

Detailed information on the residue volumes available, their location, concentration, and current market value.

WAHLENBERG, W. G.
Use of a short-handled planting hoe in the Appalachians. Tree Planters Notes 14: 6-8. April. Also in Southeast. Forest Expt. Sta. Research Note No. 26. Jan.

This short-handled hoe used in Montana and Idaho proves to be an effective tree-planting tool in the Southern Appalachians.

WAHLENBERG, W. G.

Modifying nursery stock to fit modern planting methods. Tree Planters Notes 14: 4-5. April.

Nurserymen are encouraged to grow and grade their stock to suit modern planting tools as well as to meet site requirements.

WAHLENBERG, W. G.

Three methods of rehabilitation for depleted Appalachian hardwood stands. Jour. Forestry 51(12): 874-880. Dec.

A 20-year comparison of no cutting, clear-cutting, diameter-limit cutting, and quality selection show that selection is a suitable method for preparing depleted hardwood stands for management.

WAHLENBERG, W. G.

A 37-year test of thinning Appalachian white pine. South. Lumberman 187(2345): 180-183. Dec. 15.

Management in the form of six intermediate cuttings, beginning when the plantation was 20 years old, increased the total yield in stumpage by $200. Nearly one-third of the total wood yield on the thinned plot came from thinnings. Sawtimber yields are 50 percent greater on the thinned than on the unthinned area.

WENGER, K. F.

The sprouting of sweetgum in relation to season of cutting and carbohydrate content. Plant Physiology 28(1): 35-49. Jan.

Sprouting vigor, expressed as height or weight of 1-year-old sprouts, showed pronounced correlation with date of cutting. Number of sprouts did not follow a seasonal trend, and is closely correlated with stump diameter. Size and number of sprouts is apparently not dependent on carbohydrate content.

WENGER, K. F.

How to estimate the number of cones in standing loblolly pine trees. Southeast. Forest Expt. Sta. Research Note No. 44. July.

Instructions for making a binocular estimate of cone crops, including conversion of the binocular count to total number of cones.

WENGER, K. F.

Preharvest release of loblolly pine seed trees will increase seed supply at harvest. Southeast. Forest Expt. Sta. Research Note No. 45. July.

Choosing seed trees and releasing them 3 to 5 years before the harvest cut will increase the seed cast at harvest.

WENGER, K. F.
The effect of fertilization and injury on the cone and seed production of loblolly pine seed trees. Jour. Forestry 51(8): 570-573. Aug.

Application of fertilizer at the rate of 25 and 50 pounds per tree significantly increased cone production of 25-year-old loblolly pines. Forty-year-old trees did not respond to treatment. Half-girdling with a knife produced no increase in cone crop. Treatments did not significantly affect percentage of defective cones, number of seeds per cone, or percentage of defective seed per cone.

ADDENDA

The following 1952 items did not appear in the Station's 1952 Bibliography:

HALLS, L. K., SOUTHWELL, B. L., and KNOX, F. E.
Burning and grazing in coastal plain forests. Ga. Coastal Plain Expt. Sta., Univ. Ga. Bul. 51. 33pp. Nov. 1952.

Results of a 7-year study of vegetation and cattle responses to burning frequency (1-, 2-, and 3-year intervals vs. no burning) in longleaf-slash pine forests of Georgia; ecological trends and chemical composition of forage species, diet and weight gains of young cattle, fuel accumulation, and tree reproduction. Also, general relationship between amount of tree canopy and herbaceous understory.

HOOVER, M. D., and LUNT, H. A.
A key for the classification of forest humus types. Soil Sci. Soc. Amer. Proc. 16(4): 368-370. Oct. 1952.

Previous keys based on northern forest conditions have heretofore proven unsatisfactory elsewhere. For the first time the authors have presented a key to forest humus types that is developed for the entire country.

SHEPHERD, W. O.
Forest ranging beef. N. C. Agr. Expt. Sta. Research and Farming 10(4): 11. Spring 1952.

Current forest grazing research in the cane type in North Carolina; cattle management, forage management, grazing capacity.

TOOLE, E. R.
Two races of fusarium oxysporum f. perniciosum causing wilt of albizzia spp. Phytopath. 42(12): 694. 1952.

Describes two forms of mimosa wilt fungus, one attacking A. julibrissin and one attacking A. procera (Puerto Rico).